ANALOG

SCIENCE FICTION AND FACT

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MARCH 1996

OUT OF THE WASTE LAND
by W.R. Thompson

Charles Sheffield & Jerry Pournelle

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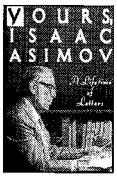

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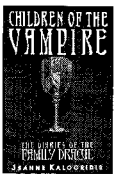

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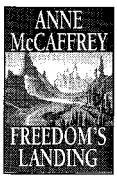

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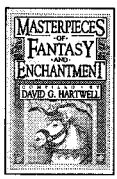

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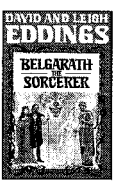

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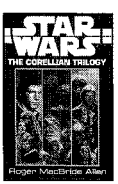

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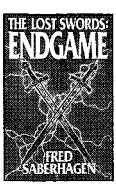

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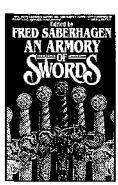

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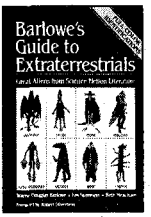

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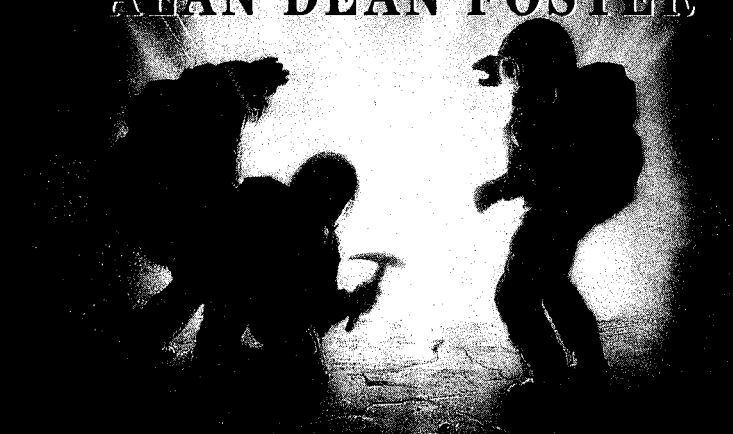

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THE FEELING OF REALITY

A rocket the size of a skyscraper stands on its pad, glowing white against the black of the sky. The searchlight beams that illuminate it seem to radiate from its hull, given visible form by the predawn mists. . . . At the moment of ignition, dazzlingly bright clouds billow forth from its base and quickly, silently fill half the sky. Slowly, then faster and faster, it begins to rise—and then the sound comes. It thunders into the sky, fading in minutes to a faint dot fleeing the planet of its birth. . . . Seen from a catwalk high in the single cavernous room of the VAB, another like it seems impossibly huge as it waits its turn. . . . Then it, too, begins the long, slow procession out to the launch pad, riding the huge caterpillar treads of the crawler-transporter. . . .

As I watched these images in the movie *Apollo 13,* they evoked powerful memories of one of the two most spectacular events I've ever witnessed. I've never ridden a moon rocket, and I wasn't at the launch of Apollo 13. But I *was* at that of Apollo 17—the last—with press credentials that let me watch the spectacle from as close as anyone except the astronauts themselves. I was able to stand close to the waiting rocket spotlighted in wispy fog before dawn, and visit parts of the Vehicle Assembly Building that were off limits to the general public. So watching those parts of the movie, 23 years later, reawakened the whole sensation of a reality that had burned itself deeply into my memory.

What I got from the movie was far more than the picture on the screen and the sound from the speakers, because for me, that was *real.* My memory conjured up, automatically and with equal vividness, all the other components that the film couldn't provide directly. I could feel the dankness of the humid air that morning out at the launch pad, and see the beginnings of a red glow chipping away at the blackness in the east. I remembered the heaviness of my eyelids from having been up most of the night, and the inability to close them because of sheer fascination.

Apollo 17 left at night, and I remembered thinking that the billowing orange clouds that followed ignition were like the most spectacular sunrise I had ever seen, compressed into a few seconds. I remembered the silhouette and wing flaps of a startled

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heron flying frantically across the glow, just a few feet above my head. And I remembered my astonishment when the sound began to arrive some 17 seconds later, because I was so absorbed in the visual spectacle that I'd literally forgotten there would be sound, too.

I remembered how at that distance, the cracks and pops of the rocket that you hear on television quickly merged into a solid, steady drone of unbelievable power—reaching me as much through the soles of my feet as through my ears. I remembered the incongruous image of a little cattle egret walking placidly along behind the crawler-transporter, eating insects stirred up by the passage of something so huge that it sank five feet into the first road built for it. I remembered the exhilaration, at a time in my life when I had actually met almost no one who worked in science fiction or space research, of spending most of the week in the company of people whose names I had known since childhood, gathered here to watch a dream we had all long shared become real.

At least, in a very limited way.

Along with the exhilaration, there was a strong undertone of sadness and doubt at the Apollo 17 launch. The last Apollo was 17, and what other future the space program had was quite uncertain. I remember seeing a group of spectators holding up a sign that said, "Apollo 17: The beginning, not the end," but their view was far from unanimous. Many people, some of them in highly influential positions, shared the extremely short-sighted view voiced by a politician in the *Apollo 13* movie: "Why should we keep funding this program now that we've beaten the Russians to the Moon?"

At the moment, it often seems that that faction has had its way. Most readers of this magazine, I suspect, view beating Russians to the Moon as the pettiest of motives for something like the Apollo program. If that's all it was, maybe it *was* a waste of money. It is perhaps one of history's best examples of doing the right thing for the wrong reasons. Its real importance should have been as the beginning of something much larger and of far wider importance—as Neil Armstrong so succinctly observed when he first set foot on the Moon.

That may still turn out to be the case—it had better, if we really care about humanity's long-range future—

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but at the moment we seem to be in a time when hardly anybody is capable of striving to realize a big vision, or willing to take the risks necessary to do so. *Apollo 13* reminded some of us of a time when some people *did* share big visions and weren't afraid to take risks—and suggested the possibility of such attitudes to people too young to remember them.

But I found myself wondering as I watched it: how many of those younger people—say, under 30 or so—see them as *real* possibilities? For me, the movie was a powerful reminder—because I've been there. But how many of those too young to remember could get anything like what I got from its images? How many of them really grasped the fact that this was not science fiction, but something that actually happened?

If they could, such a movie, seen by many people young enough to have their imaginations fired and young enough to *do* something about it, could contribute a lot to the renaissance of a real space movement. We might even see a new generation emerge that could dream big dreams, accept the need for big risks to achieve them, and respect people willing to take those risks.

But only if they could see such things as real possibilities in the real world, not "just another story." People in general find that notoriously difficult. It's far easier to care deeply about something when it touches you personally than when you've thought about it only in the abstract. I've seen the same people park without a

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thought in a handicapped space for which they had no need—and go far out of their way to help a handicapped individual with whom they came face to face. I remember people devoting vast amounts of time and energy to opposing the Viet Nam War on philosophical grounds—but becoming a good deal less vocal in their opposition when they themselves ceased to be draft-prone.

A character in a novel of mine (and I with him) once agonized long and hard over the question of how to make people care enough to try to solve a big, long-range problem that would take a long time to solve, but whose solution wouldn't be urgently needed very soon. The only answer either of us could come up with was to convert it to an immediate, short-range, *personal* problem.

Humanity's need for space is that kind of a problem. You won't get many people to care about it until they perceive it, at a very deep level, as personal and *real*. The story of *Apollo 13* is real—but may be difficult to perceive as such for anyone with no personal memories of that project and the excitement people felt about it.

On the other hand, writers and movie makers are in the business of creating the feeling of reality, whether they're writing about real events or made-up ones. As well as I can tell, from my admittedly somewhat biased viewpoint, the makers of *Apollo 13* did a good job of that. So maybe it doesn't really matter that much whether viewers perceive it as something that *did* happen, or just something that *could*. Either way, such a movie—and perhaps others like it—just may play a significant part in stimulating a new generation who can dream big, and won't be afraid to be heroes. ■

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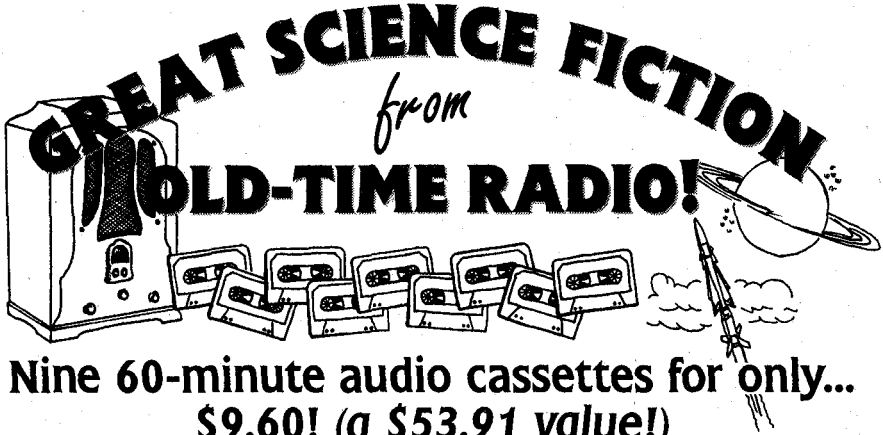

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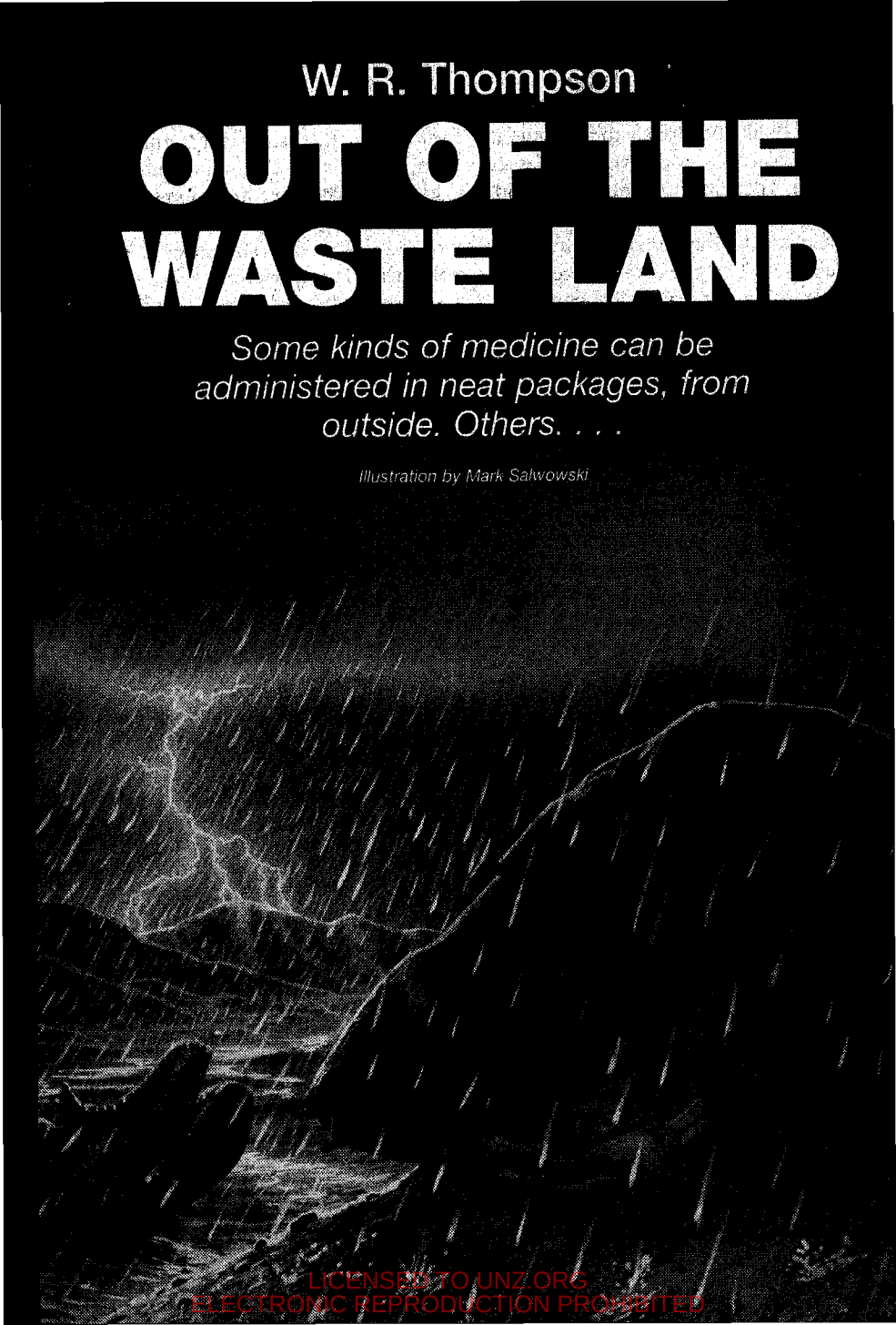

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The desert Sun was so bright that it almost blinded Margaret as she stepped out of the van. She blinked furiously for a moment and wished she could wear sunglasses again. Then she remembered her options. A sensor built into her silvery helmet's rim measured her eye movements and fed the data into her computer, allowing her to click on the optical icon and drag the cursor across the Sun symbol. The eyeplate adjusted itself and began to reflect away some of the Mojave sunlight.

Once her eyes had recovered from the glare, Margaret clicked on her movement icons and looked around. Her head turned with none of the jerkiness she had known during her first weeks of therapy, and she got a clear, steady look at her surroundings. The van had stopped at a gas station in a small desert town—a few cinderblock houses with chicken coops and dish antennas in their sunbaked yards, a diner, and a convenience store. She had seen more impressive ghost towns. Dead, weed-choked ground stretched away from the town in all directions, while barren, eroded hills rose up a few miles to the east and north. The brown and tan colors of the land looked baked and dry.

The van's driver seemed to read her mind; she realized he must have made this trip dozens of times. "It's just a jumping-off point," he told Margaret. He pointed to the badlands north of the town. "The big city is out that way."

Margaret keyed in her speech icons. A symbolic keyboard appeared in the heads-up display of her eyeplate. Deftly, she looked at the translucent letters and icons, building up her answer one letter at a time: H, O, W, *speak,* F, A, R, *speak.* Her helmet's computer relayed the commands to what was left of her neural system, and her lungs, larynx, and mouth worked. "How far," she asked. Her voice was flat; intonations were too complex for the computer to handle.

"Fifty, sixty miles," the driver said. "It depends on what path Ringo likes."

The station attendant came out of the service bay. He was a teenage boy in a greasy Texaco shirt. He didn't look at Margaret, which annoyed her. He must have seen this van and its driver often enough to know that the passengers were rehab patients from the UCLA Medical Center. That made her something less than a woman in his eyes. "Fill it?" he asked the driver.

"Yeah, and check the oil," the driver said. He looked around impatiently as the boy uncapped the gas tank. "Where's Ringo?"

"It's Geisler to you, scumbag," a man's loud voice said. He walked out of the service bay and Margaret looked him over: big without being fat, scruffy beard and long graying hair tied in a ponytail, blue jeans and a black Harley Davidson shirt. He wore several silver rings on each finger, and Margaret saw his fingers wiggle with each step he took. A paraplegic, she guessed, still using the old-style limb stimulators instead of implants. "Anyone calling me 'Ringo' better have a widow named Yoko."

The driver ignored his complaint. "Are you ready to go?" he asked.

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" 'Ready,' hell," Geisler said. He patted his waist, and Margaret saw the bulge of a battery belt. "Eveready, man."

"Well, good," the driver said, " 'cause I have to be back in Westwood before—"

"Tough," Geisler told him. He turned to Margaret and stuck out his hand. "Tom Geisler. I'll be your guide."

Margaret clicked on her dexterity icons and placed the palm of her hand against his, then switched back to her speech icons. "Margaret Danes," she said as they shook hands.

"Good to meet ya, Maggie," Geisler said. "You ready?"

Now there's a loaded question, she thought; she still wasn't sure what to expect from what the therapists had told her would be a "wilderness survival experience." Hiking through the California desert in the middle of June hadn't struck her as a good idea, but she hadn't wanted to argue with her therapists; she had been wrong about too many things to trust her judgment anymore, a thought she quickly dismissed. "My pack is in the van," she said.

"Let's see what you got before we saddle up." Geisler went to the van's rear hatch and opened it. Margaret followed him and saw him scowl at her orange backpack. "Jesus," he grumbled as he opened it and started pulling out survival supplies. He tossed most of them aside: Halazone tablets, a large first-aid kit, a tube tent, instruction manuals, and other odds and ends she couldn't identify. "Hey, weenie!" he shouted at the driver. "Don't you people ever learn?"

The driver joined them. "What's your problem, Geisler?"

"It ain't my problem," he said, "it's yours. You idiots loaded her up like a pack mule. When was the last time you brought me somebody who could carry sixty pounds of crap?" Geisler turned to Margaret and looked her over. "Nothin' personal, but there's no way you can carry all that junk."

"I know," she said. Exercise—endless hours on treadmills and machines, her body working in response to preprogrammed instructions from her helmet—had restored some of the muscle and endurance she'd lost during her illness, but she knew she still looked frail. "What do I need?"

"Not much," Geisler said, as the driver wandered off. He finished emptying the pack, then retrieved a few items. He spoke as he crammed them into the pack. "Your sleeping bag. Suntan lotion. Toothbrush. Toilet paper. Salt tablets. What's this?" he added, picking up something that looked like a roll of blue metal foil. A wire dangled from one end of the roll.

"Solar battery recharger," Margaret said. "I need it. And the cleaning fluid. For my eyeplate."

"OK." Geisler zipped up the pack and handed it to Margaret. Quickly, she clicked on her dexterity icons and maneuvered her hands to take the pack. Her fingers wrapped around a shoulder strap, and she threaded her free arm through its loop. Last night she had spent a half-hour practicing the maneuver of putting on her backpack. The practice helped, and she

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was able to get the load in place and snugged down with little difficulty. Her neural prosthetics told her that the pack was much lighter than it had been last night, and when she took a few experimental steps she found it easier to move. Her body seemed to shift around less, too; with the lighter load on her back, the helmet's sensors had less trouble maintaining her balance as it automatically worked certain leg muscles to keep her upright.

The attendant had washed the van's windows, and as Margaret turned around she saw herself reflected in a window. The helmet covered her head, protecting the computer and the thousands of hair-fine electrodes implanted throughout her brain, and holding the display's glass plate in front of her eyes. The smooth metal dome only emphasized the hollowness of her cheeks, reminding her of what she'd gone through. Illness, surgery, therapy, Lydia's death—

She couldn't think about that. She forgot about it. Geisler had walked away, going behind the gas station. Margaret went after him, and found him standing next to an old black motorcycle. He stood with his legs apart to keep himself braced as he dug into its saddle bags. He slung a bedroll and a rucksack over his shoulders, then buckled a web belt with a pair of canteens and a small first-aid kit around his waist. "You ready to roll, Maggie?" he asked.

"Yes."

"Guess again." He pulled another pair of canteens from his saddlebags and handed them to her. "Last thing you want to do is walk into the desert without water," he said, as she fumbled with the belt that held the canteens. "You can get dehydrated in no time. Sunstroke, too. Where's your hat?"

Margaret buckled the belt in place, then switched to her speech icons. "I don't need a hat," she said. "The helmet is designed to reflect heat. It's been tested."

"Yeah?" Geisler shrugged. She found herself envying the easy naturalness of that gesture. Body language was one of the many things she had lost: the simple ability to express feelings through natural changes in posture. "Well, I've worn helmets in hotter places than this, and I didn't fry my brain too bad. Let's go." He turned and started walking.

"How far?" Margaret asked.

He shrugged again. "Ten, twelve miles today. C'mon."

Margaret hesitated as Geisler kept walking. The ground beyond the gas station looked reasonably flat, but it was choked with weeds and dried-out desert growths, and there were angular rocks everywhere. She clicked on the autowalk icon, but before she could set the cursor to draw out a projected path the computer flashed a message on her display in indignant red letters: *Terrain too rough. Advice: [1] Choose smoother terrain. [2] Use manual guidance.*

She wondered what idiot had decided to send her out on ground as rough as this. For a moment she thought about getting back in the van and returning to Los Angeles—except—damn it, that would mean admitting she couldn't handle this. Ad-

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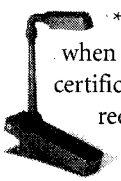

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mitting she was a cripple, and having to listen to more feel-good talk from the therapists. No way, she told herself, no way in hell.

And this place looked like a good approximation of hell. One more mistake, she thought in disgust. Another mistake in a lifetime of mistakes. Wrong husband, wrong doctor, wrong everything. It had all brought her here, leaving her unable to do anything for herself except move her eyes and blink. A basket case, reanimated by a computer and moving like a marionette in a land as dead and barren as her life.

She clicked on her movement icons, identified a stretch of dirt ten feet long that looked fairly smooth, and placed the cursor at the end of the stretch. The computer took control and obediently moved her legs, left, right, left, walking her over to the spot she had marked. Another icon let her step over a large rock, and then she was able to cross a dozen clear and level feet of desert ground before she had to stop to evade a dead clump of brown, shrub-sized weeds. She turned a bit to the left and made it across two yards of clear ground before hitting another obstacle.

Geisler had walked on a hundred yards ahead of her, before he stopped to watch her zig-zag her way across the ground. "Somethin' wrong?" he called to her. Then, after a long silence: "Well?"

Margaret stopped, looked at him and switched to her speech icons. She raised her vocal volume to make sure he heard her. "Nothing is wrong. I can't move any fwster."

Geisler looked blank. " 'F'wister'?"

"Faster," she said in irritation. Every time she misspelled a word the damned computer made her mouth generate some idiot-sounding noise. It didn't help that the machine got confused over some of the English language's more idiosyncratic rules. *P'seechowtherapy. K'nuckless. Wurist.* Every night (which the computer had originally pronounced as "ni-gut") she had to spend time programming in correct pronunciations.

In her first hour after leaving the desert town Margaret had barely walked one mile. When she looked back she saw the van was still there, parked in front of the diner. Too late to turn back, she thought wryly; by the time she could thread her way back the driver would have finished his meal and left town. Of course, she had a cellular modem built into her helmet, so she could call for a ride—no, forget it.

Geisler stopped at the end of the first hour, took a drink from one of his canteens, then held it out to her. "Don't drink too much right now," he cautioned her. "There's a supply cache about ten miles from here, and what we're carrying has to last until we get there."

Margaret swallowed some water, then lowered the canteen. She decided against trying to screw the cap back in place; she had practiced that maneuver, but she wasn't very good at it and didn't want to risk spilling any water. She handed the canteen to Geisler and switched on her speech icons. "I'm walking faster now," she said.

"Yeah, I noticed," he said, as he capped the canteen and hung it on

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his belt. "The ground gets sorta smoother in another mile or so. There's a dirtbike trail along the foot of the hills. It'll go straight to the number one cache."

"That sounds better."

"Yeah, well, it's gonna get a lot hotter before it gets any cooler." Geisler took off his hat and wiped at his forehead, then looked her over. "You look OK so far, so I guess you'll make it. One thing, though. I guess you can't walk and talk at the same time?"

"Right." She thought about explaining how she had to switch between her different control icons, then decided against it. "Maybe I'm qualified to go into politics."

Geisler laughed and put his hat back on. "Let's get going."

The trail was a set of ruts which ran along the foot of the dusty hills. It was broken by gullies and boulders which had tumbled down the craggy slopes. The trail was not much smoother than the desert floor had been, but Margaret was learning how to walk on it with reasonable speed.

Late in the evening they found a V-shaped pile of stones at the mouth of a ravine, and Geisler swore at it in disgust. "They should know better," he complained to Maggie, as he led her up the ravine. "Hell's bells, I *told* them better."

Margaret followed him in silence. Whatever the problem was, she knew he would tell her sooner or later. He had kept up a fairly steady monologue throughout the day, filling her in on desert lore and history. He had also asked after her health from time to time, saw to it that she took enough water and salt tablets to make up for her sweat losses, and made sure she kept her exposed face and arms slathered with sunscreen.

"Ninety-eight, ninety-nine, a hundred," Geisler grumbled, his fingers wiggling methodically as he counted off his paces. He stopped and looked around the ravine. "Yeah, there it is, lucky us." He walked up to a boulder, where a steel drum painted Dayglo orange sat in its shadow. He pulled off its lid, looked inside, and pulled out something. "Take this and head back to the trail. No way are we camping *here*."

Margaret took the burlap bag he handed her and walked back to the ravine's mouth. He followed her a few minutes later. He had tied a rope to the drum's handle, and looped the rope's end around his shoulders like a harness. His fingers worked as he operated his leg's control rings. "Goddamn brainless wonders," he panted. "Never think about . . . how I'm supposed . . . to walk and carry crap . . . same goddam time."

"Let me help," Margaret said.

"You'll goddamn have to help, Maggie," Geisler said. He pointed to the hillside, where a barely-visible trail ran up to a smooth ledge under a rock face. "That's our campsite, and there's no way I can carry this stuff up there."

"They may have had that in mind," Margaret said.

"What, to make you do somethin' therapeutic?" Geisler sat down and wiped sweat from his face. "Figures. OK, get therapeutic. I'm too old for this crap."

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Margaret took the bag he had given her before and carried it uphill to the ledge. The path wasn't too bad, she noted, and when she clicked on the autowalk icon the computer was able to take her uphill without asking for her guidance. That came as a welcome change of pace. After having to think about almost every step she took for the past dozen miles, Margaret was glad to let the computer do some work.

She needed a half-dozen trips to remove all the supplies from the drum and carry them to the ledge. Geisler started cooking dinner while she worked, and he had the camping rations ready by the time she had finished. "Bet you've worked up an appetite," Geisler said, as he handed her a Styrofoam cup of stew.

"I don't know," she said, after she had sat down. She felt awkward about making conversation; using her icons made it impossible to maintain eye contact as she talked. "My implants only give me surface sensations. Touch, pressure, temperature. I can't tell if I'm hungry."

"Yeah? Well, you'd better eat like you're hungry. Tomorrow's going to be worse, count on it." There had been an envelope in the drum. He took a bite of beef jerky, then chewed on it as he opened the envelope and looked at the map it contained. "Great. Cache number two is only eight miles from here, and when it's that close you can bet it means we have to do something stupid to reach it. Those idiots in Westwood love that scavenger-hunt stuff." He stuffed the map into his pants pocket. "I just had to get mixed up with this therapy business."

Margaret stopped eating long enough to ask a question. "Why?"

"Money," Geisler said. "You know how much it takes to keep a Harley in gas, insurance, and parts? Plus my medical bills, and room and board? At least this job lets me ride when I like and live where I want. Plus, every so often I get to meet some good-lookin' babes."

That sounded strange; she knew how the helmet had changed her appearance. "You think I'm good-looking?" she asked.

"Yeah. That helmet kinda makes you look like the queen of the Amazons." He chuckled. "I used to ride with a gal that wore a helmet like that. You ever ride a Harley?"

"No. I'm a librarian."

"Yeah? I met some librarians at Sturgis last year. That's a big biker rally in South Dakota. You might like it." He looked at the horizon. "Hey, we'd better recharge before the Sun goes down."

"I know." She put her stew down, opened her pack and got out her recharger. She unrolled the solar-cell foil on the dusty ground and clipped its wire to a strip on her helmet's rim. A yellow message blinked in the corner of her eyeplate: *Recharging. Battery level: 83%.* The battery held enough power to last several days, but she felt more secure with a full charge. She wished she could have kept the recharger hooked up while she was walking, but if she fell down or stumbled into something she might wreck it.

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Geisler had taken off one of his battery belts and plugged it into his own solar panel, a bigger, clunkier version of her recharger which he had propped against a boulder to catch the Sun better. His old-fashioned prosthetics were nothing like hers, she knew. Underneath his trousers, a network of electrodes would stimulate his muscles with power from the batteries, making the muscles contract in galvanic response. That consumed more power than her system, and it was more vulnerable to damage and breakdowns. "Why don't you use implants?" she asked in her flat voice.

"What, and let some mad scientist wire a computer into my brain?" He snorted in derision. "The only way anyone is gonna play games with my head is if they cut it off and dribble it like a basketball." Then he looked abashed. "I guess you didn't have much choice."

"No." She didn't want to talk about what had happened to her. "What was wrong with putting the cache in the ravine?"

"Two things," he said. "One, there's vandals. Some punks ride their dirtbikes along the trail, see a pile of stones pointing up a ravine, and get curious. Next thing you know, they steal what they like and mess up the rest, and we're up the creek without a paddle. Or without a creek, out here." He chuckled nastily. "It's a long, dry walk home. They shouldn't be so obvious about marking a cache. The next one might be gone."

Margaret didn't like the sound of that. "We could phone for help," she said.

"Out here?" Geisler made a rude noise. "Maybe a cellular phone would work if you climbed to the top of a hill, but I wouldn't count on it. Phone service is spotty out here."

"So we're on our own."

"Yeah, well, that's the general idea." He picked up a stone and chucked it at the trail. It landed in a puff of dust. "Second thing that's wrong with using a ravine is rain. The other day they choppered in the supply barrels and cached them here and there. If we'd had a good thunderstorm before we got here, that barrel would have been washed halfway to Barstow, and we'd be back up the dry creek."

"That mich water?" she asked. She realized she was tired; although she felt no fatigue, exhaustion was making it difficult for her to work the speech icons. "Storms give inch of rain. Or less."

"Exactly," Geisler said. "And out here it doesn't take much rain to make a real gully-washer. It just rolls off the slopes and funnels into the ravines, and the next thing you know there's a real blast running through all these ravines. See how the dirt and gullies spread out there?" He waved a hand at the ground below the mouth of the valley. "That's an alluvial fan, made from dirt washed out by different storms. Those boulders were moved by water and gravity, too, and you can guess how big a flood it took to move rocks that size. That's why we're camping up here," he went on. "If a storm blows up while you're sleeping in an arroyo, the flood will smash you into the rocks so hard that

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you won't live long enough to drown."

"Oh," Margaret said. She tried to pick out the icons carefully. "Does it rain often?"

"It varies," Geisler said. "Last year was bone dry. This year, though—" He shrugged. "The California Current shifted last winter and we're getting these killer storms out of the tropics. The satellite shots didn't show anything moving our way this morning, but that can change by tomorrow." He shrugged again. "Look, it's June. The odds are that we won't get any rain this late in the year. I just don't believe in taking airheaded chances."

"Oh." Margaret returned her attention to her dinner. The stew had grown cold, but she didn't care. She had lost her sense of taste and smell, and all food was equally bland to her. Eating was a chore similar to recharging her helmet battery.

Later, as the Sun went down, she unrolled her sleeping bag and inflated its pillow. She needed it to support her helmet, which was surgically attached to her skull; too much weight or pressure might have dislodged the connections between the computer and her brain. Geisler had no such problem. He spread his bedroll on the dirt and went to sleep at once.

Margaret lay awake for a while. At first she regretted not having her tent. It was only a simple plastic tube and a few collapsible poles, she told herself; she could have carried its extra pounds. There were poisonous insects out here, as well as snakes and coyotes, and she would have felt more secure with a roof of some sort over her head. It was cold, too; now that the Sun was down the desert heat fled into the clear black sky.

As she looked at her eyeplate she decided to program in a new movement icon. Blinking and moving her eyes with practiced ease, she called up several menus and selected specific items from each of them: contract both trapezius muscles to raise the scapulae and clavicles. Spread both hands slightly, palms out, with a slight turn of the radius and ulna in both arms. Then, create an icon and add it to the appropriate screen, to be called up and clicked on as needed.

She closed her eyes. All this, she thought, just so she could shrug.

The sunlight woke her at dawn, and after they had breakfast Geisler filled their canteens and finished recharging his batteries. He insisted on having all of their refuse packed into the steel drum, and Margaret made several trips up and down the hillside to clean up the ledge. "Junk lasts forever out here," Geisler said as she finished, "and I *live* here."

"So do scorpions," she said, with an irritation her voice couldn't express. He couldn't carry anything in his hands when he walked, which had left her to do the cleaning. That work had been complicated by the way her body trembled. Cold, she thought. The night sky had seemed to leach the heat from her even through her sleeping bag, and although she had only a vague sensation of being cold, she still shivered.

"Yeah?" He chuckled. "Well, scorpions are mean neighbors, so you don't want to piss them off by being a slob.

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You want to visit the powder room before we go?"

"No." What she *wanted* to do, she thought, was spend an hour or two in a bathroom with a full tub. Her neural prosthetics didn't give her a sense of discomfort, but she *felt* grimy.

Geisler checked the map again as she put on her backpack, then looked up at the clear blue sky. "Gonna be a real scorcher today," he said, "but if we keep moving we can make the second cache before noon."

"You said there might be trouble," Margaret said.

"Uh-huh." He started walking downhill to the trail. He kept talking as she followed him. "We'll probably have to do something *clever* to get it—improvise a ladder, find a way to pry open the lid—well, don't sweat it."

Sweat the walk instead, Margaret thought. She kept the thought to herself, however. The trail was still too rough for her computer to navigate, and she had to give her attention to walking and maintaining her balance. The morning's chill was quickly replaced by heat as the Sun rose higher in the sky.

Geisler called a break when they reached the mouth of an eroded canyon between two low hills. "The second cache is up thataway," he said as they sat down in the shade of a boulder. "It's supposed to be exactly one mile from here, on the side of the hill. The sunny side, naturally."

"Do we go now?" Margaret asked. Only the skin on her face could feel the heat, but she knew the hot air and Sun were taking a toll on her body. She wasn't eager to get up and start walking again.

"Let's take five before we move out," Geisler said. He took a canteen from his belt, drank and passed it to Margaret. "You ever hear anyone say that Arabs are lazy? Well, that's a crock. Bedouins and Tuaregs live in slow motion because that's how you get along in the desert." He looked at the horizon. "Damn."

"What?"

"Cirrus clouds, coming in from the southwest, just like the wind. Maybe it's nothing, but it could mean rain later today."

"Oh. Do you have a radio for a forecast?"

"No, because the local forecasters are all worthless." He pitched his voice to a nasal whimper: " 'Maybe it'll rain, unless it doesn't.' Only forecast I trust is the one I make by looking at the satellite photos, and before you ask, no, I didn't pack along my sat-TV."

"Oh." Just the same Margaret activated her computer's modem, to see if she could download a forecast from the computer net. To her disgust she got nothing but an error message which informed her that the modem could not locate the cellular phone system. Geisler had warned her that the phone service was unreliable in the desert, but it didn't please her to have his word confirmed.

He chuckled. "Told you so. The phones aren't much use out here."

That comment surprised her. "You know I tried to make a call?" she asked.

"Uh-huh. I saw a phone icon on your glass. Don't worry about calling

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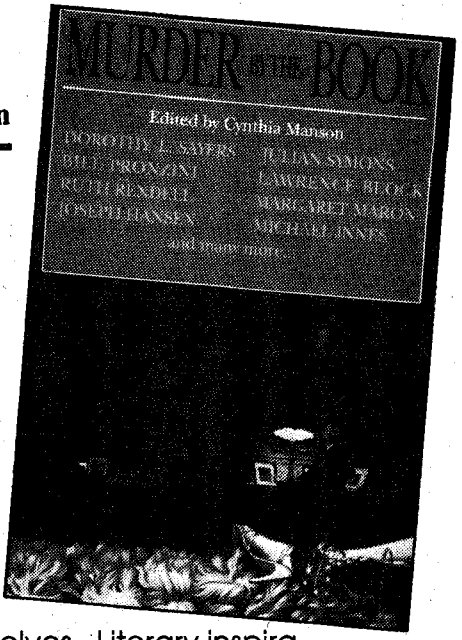

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for help." He patted his hip pocket. "I brought along an emergency radio. CB channel nine, satellite transponder, Highway Patrol, Civil Air Patrol."

"Radio works out here?"

"Some frequencies, yeah," he said. "The cops and the CAP use frequencies that don't depend on line-of-sight, and there's always a GPS-2 satellite above the horizon, so we're covered."

"Oh." Margaret looked at him. Yesterday she had dismissed what he had said about computer implants; he had come across like some weird old desert bum. Now she didn't feel so certain, and she wondered what he had against implants. "You seem to know a lot," she said.

He looked her over for a moment, and she knew that her toneless voice made him wonder how she had meant that remark. He finally shrugged it off. "After I broke my back I spent a lot of years in a wheelchair. When I couldn't find a job, I'd do a lot of reading, and take courses at a community college. It beat the hell out of vegetating and wishing I could hop back on my Harley."

"You don't think much of implants," she said.

He snorted. "And you think I've got some educated reason for that, instead of some ignorant biker reason?"

"If I knew, I wouldn't have to ask."

"Good point," he said grudgingly. He drank from one of his canteens. "OK, look. A few hundred million years ago our ancestors were worms. All the brains they had were just a tiny clump of nerves. Well, some of them evolved into fish. They didn't get new brains; what they did was to add a new layer to their old brains. When they evolved into amphibians, they added a few new layers of brain tissue. The next step, the reptiles, added more layers. So did the mammals, when they came along, and the monkeys added the last few layers. Each new chunk of brain evolved to handle a specific task—recognizing a bit of food when it floated in front of a fish, figuring out the distance to a branch when a monkey had to jump from tree to tree, whatever.

"That's why our brains are this complicated mess of things like the neocortex and the R-complex and the amygdala, instead of one smooth, uniform collection of nerves. And that's why we've got intelligence. All of the different bits of the brain only do one job, but they also coordinate with one another, and when they run into a problem, they pass it around from bit to bit until the problem lands in the lap of whatever chunk of the brain is designed to handle it."

"I know," Margaret said. She had heard that was the latest trend in artificial intelligence research. Scientists were trying to make a computer that was as smart as a human by linking together many small, specialized circuits into a coordinated network. Some of their techniques were used in her computer, making it the equivalent of what Geisler called "a chunk of the brain."

"If you know it all, I don't have to explain," Geisler said. He shrugged after a moment of silence. "OK, I like hearing myself talk. All of the brain's little chunks know how to work together. If you have a stroke or some-

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thing, they'll try to learn how to work without the missing part. So what happens when you patch a computer into that arrangement?"

"All my computer does is replace a few of the damaged parts of brain," Margaret said. "It gives me a sense of touch and activates my peripheral nervous system. It doesn't interfere with anything."

"Bull," Geisler said. "It reads your brainwaves like an encephalograph would, and all those electrodes pump in electricity and stimulate parts of your brain. It also links together some of the areas that were separated when you got sick. That's what I call interference, and I doubt the doctors know everything it does. Maybe your brain is going to learn how to use that implant, until the two kinda melt together."

"Good," she said. "Maybe then I'll be able to move and talk without needing these damned icons."

"And maybe by then you won't know if you're a computer or a woman," Geisler said.

"You're a real comfort," Margaret said.

He shrugged. "Well, hey, that's part of the service."

"I see." She looked at him for a moment, and found herself thinking of something that seemed obvious—now. "Did they tell you to keep an eye on me?"

Geisler snorted. "They didn't have to," he said.

"That doesn't answer my question," Margaret said.

He shrugged. "They said you might try to waste yourself."

Suicidal impulses? she thought in surprise. "I've never thought about killing myself."

"Yeah?" He didn't sound like he believed her. "They tell me you're a prime candidate for the easy out, lady. They ask you about your daughter and your husband, and you clam up."

"How would you know?"

Geisler chuckled. "Community college, remember? I took a lot of courses on psychology and therapy—how do you think I qualified for a job taking folks like you on therapeutic excursions?"

"So they briefed you on me."

"Uh-huh. What they told me was, you, your husband and your daughter got immunized against the Hanoi flu last year, when everyone expected a killer epidemic. Only you and the girl had a bad reaction to the shots, because you both have the same defective gene. The shots ate away at your central nervous systems. You lived because they got you into intensive care in time, but it hit your girl harder and she died.

"OK, the girl inherited that gene from you, so you blame yourself for her death. Only, so does your husband, because he's the sort of guy who needs to blame somebody. You were learning how to walk again when the creep filed for divorce. He dumps a load of guilt on you, and then he dumps you like garbage. With problems like that, you've got *reason* to end it all."

"I know." She felt her head buzzing. Everything he had said sounded distant, as though he had been describing something that had happened to a

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peasant in ancient Sumeria. "But I haven't thought about killing myself."

"If you say so," Geisler said. "But from what they tell me, maybe you haven't thought, period. I figure you're blocking it out, which is the sort of thing that catches up with you."

"You want me to talk about what happened."

"That's part of my job."

She clicked on the movement icon that made her nod. "What do you want me to say?"

He shrugged. "Your girl's name was Lydia, right? How often do you think about what happened to her?"

Margaret tried to think. It was difficult, like trying to multiply several large numbers in her head. She felt herself losing track of everything. "I don't know. I don't have much time for thought. There's therapy, and I have to practice speech and movement on my own, and program in new movement and dexterity icons every time I need to do something new, and—"

"Don't change the subject."

"Not changing it," Margaret said. "Just explaining why—"

"You lived and she didn't," Geisler said. "How do you feel about that?"

It was a moment before Margaret could work her speech icons. Geisler waited patiently through the silence. "I don't know," she said. "I wish it were the other way around, but it isn't. Do you think my implant has something to do with how I feel?"

"No," he said, "you're doing it to yourself. You had more than you could handle, so you blanked it out. People do that, to give themselves a temporary break. But you're making it permanent."

"Maybe," Margaret said. "Look. Our canteens are almost empty. We should talk about this later."

"Yeah, right," he said sourly. He stood up. "Let's get to the next cache."

Margaret got up and followed him. The trail ran along the hillside, well above the canyon floor. The path seemed little smoother than the rough, steep ground all around her, and she spent an hour picking her way along. The breeze began to pick up, and dust started to fog her eyeplate, forcing her to stop several times to wash it off.

I haven't let myself think about it, she told herself as the computer walked her across one of the few smooth strips of path. Quite deliberately, Margaret stopped walking and tried to think about . . . it. Why Lydia was gone. Why Alan was gone. She tried to focus her attention on her memories, but it was like trying to look at something in her eye's blind spot.

The computer. She wondered if Geisler could be right about that. Maybe it was doing something to her mind. It wasn't natural to feel this lack of grief and loss. She should have felt something; Lydia deserved it.

But she could remember Lydia before her death. A lovely six-year-old having a normal childhood. Father's chin, mother's hair, nose, and cheeks distinctly her own. Her favorite videotape had been a Bolshoi Ballet production of *Swan Lake*; she had liked to sprawl in front of the TV and ad-

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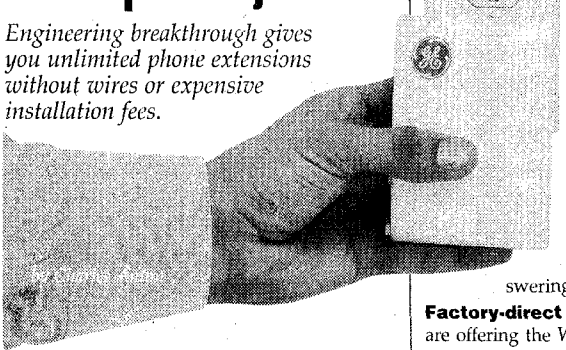
TECHNOLOGY UPDATE

New device turns any electrical outlet into a phone jack

Engineering breakthrough gives you unlimited phone extensions without wires or expensive installation fees.



by Norma Grube

You don't have to have a teenager to appreciate having extra phone jacks; we all wish we had more jacks in the house. Would you believe adding extra phone jacks in your home could cost up to $158?

Now, a breakthrough device lets you add phone jacks anywhere you have an outlet. Without the hassle, expense, and best of all, without wires.

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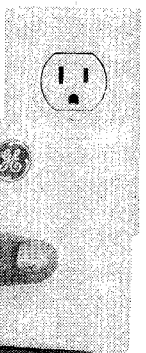

Unlimited extensions, no charge. Ordinary phone lines can usually only handle up to five extensions. But one Wireless Phone Jack transmitter will operate as many receivers as you want. Six, ten, there's no limit. Plus, you will never get a monthly charge for the extra receivers. This breakthrough technology will fulfill all your single-line phone needs. Its digital interface even works with your fax machine, modem and answering machine!

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mire the pretty costumes the ballerinas wore. Alan had taken that tape after—

Keep walking, she told herself. This hike was only a form of therapy, but the Sun and scorching air were real. She needed to reach the water in the next cache before she could think about less immediate problems. She started walking again. The trail curved up the hillside and came to a fairly smooth and level stretch of ground. As she reached that, Margaret felt absurdly pleased by the sight. It appeared she would be able to walk at least a hundred yards without trouble here. This was the best ground she had seen out here.

Then Geisler cut loose with a string of profanity. "Trouble?" Margaret asked, as she came up behind him.

"Yeah, trouble," he said in disgust. The path came to a dead end at a gully which cut across the slope and emptied into the main arroyo some fifty yards away. The gully was fifteen feet deep and ten feet wide, and it was crossed by a crude bridge: a wooden beam four inches square, with two guide rails made of rope at waist height. The guidelines were held in the ground by long iron stakes, and they swayed in the breeze. "No way am I crossing that," Geisler said.

"That must be the idea," Margaret said. His fingers couldn't operate his prosthetics while his hands clutched the lines. "I can handle it."

"Uh-huh." He looked up at the sky. "Better move. Those aren't rain clouds, but I don't like what this wind is doing."

"Dust storm?" she asked.

"Right, dust storm. Now move."

Margaret went to the bridge and hesitated. Until now she'd never encountered a situation like this. Just how did you cross a rope and wood bridge? She had no movement icon she could click on, to let the computer guide her body like a marionette.

Marionettes, she thought suddenly, operated through crude, basic movements. That was the trick. She stepped up to the end of the bridge and grasped the rope guidelines. Then she selected a set of basic icons. Right foot forward. Right foot down. Left foot forward. Left foot down. Release right hand. Move right hand forward. Put right hand palm on rope. Grip rope. Release left hand. Motions repeated with painful slowness, made even slower by the shifting of her body as the helmet struggled to keep her in balance against the buffeting of the wind, which was rising. Putting her foot down on the beam with each step was even trickier.

At last she was across the bridge. "I'll go look for the cache," she told Geisler, who stood at the far end of the bridge.

"Don't talk, *do!*" he called.

The ground beyond the bridge was even rougher than the path she had followed so far, and as the wind gusted in the narrow canyon it filled the air with swirls of tan dust. Her eyeplate worked like goggles, but even so she almost missed the cache in the thickening haze: a pile of canteens and a sack of freeze-dried food. Margaret slung the canteen straps over her shoulders and took the sack. She looked inside and saw the map which

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marked out the trail to the next cache. Then she headed back for the bridge.

The wind was howling when she reached the bridge. Geisler was gone, and one of the guidelines was down, its iron stake pulled out of the ground on the other side of the bridge. Another part of the therapy? she wondered, before she looked down into the arroyo. Geisler lay on the rocks at its bottom. He looked unconscious.

Margaret clicked on her modem and tried to phone for help, but when she hit 9-1-1 the eyeplate flashed an error message at her. So much for calling in the cavalry, she thought, as she wondered how she was going to get Geisler out of the crevasse.

She shucked her backpack and the canteens, and looked at the bridge. She didn't see how she could cross it now. The iron stakes on her side of the bridge remained in place, but one of the ropes lay draped down the side of the arroyo. Its end remained tied to the rod which had pulled out of the ground; the bent stake lay a few yards from Geisler.

He's supposed to be the survival expert, Margaret told herself; he'll know what to do. First, however, she had to reach him. She moved along the edge of the arroyo until she found a spot in its side that looked less jagged than the rest of the wall. She hesitated a moment, then began to pick her way down the mess of boulders and rock ledges, using every handhold she could find during the cautious descent.

Lowering herself fifteen feet took as many minutes, and she needed as much time to reach Geisler. He was conscious now, and he had propped himself up against a boulder. He had ripped open a pants leg, exposing the wires and control pads of his manipulator. He had also tied a gauze compress over his shin, and Margaret saw bruised flesh and drying blood around the bandage's edges. "What happened?" she asked.

"I was born an idiot, that's what happened," he growled. He spat and wiped dust and sweat from his face. "The wind blew and I started to lose my balance, so I tried to grab a rope." He held up a hand and clenched a fist. "Goddamned controls. I made myself kick like a prima ballerina, and I went over the edge."

"Can you walk?"

Geisler shook his head. "Ripped out a bunch of wires. At least I can't feel nothin' down there."

"Radio," she said.

"Already tried it," he said. He reached out and picked up a twisted plastic card which lay in the dirt. "It gave its life to help break my fall. You can bet I'm gonna write the maker and bitch about their 'indestructible' guarantee."

"We have to get you out of here."

"Don't I know it." He jerked a thumb at the sky, which was obscured by blowing dust. "This wind's coming from the southwest, and right before I fell I saw black clouds on the southwest horizon."

"Rain. Coming this way."

Geisler nodded. "You've got one hour, tops, before this arroyo turns into a garbage disposal. The way you move, you have just enough time to get out of here. Get uphill. I saw a

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rock face up there; it'll shield you from the water. Stay low to the ground, too. You don't want to draw lightning."

He's telling me he won't make it, she thought. He was right; there was nothing she could do. That realization made her feel like—like—the way she had when Alan had blamed her for Lydia's death. Not angry, not hurt. Frustrated, as he blamed her for one mistake, then blamed her for another before she could work her speech icons quickly enough to answer his first accusation. Then left her alone, to bear everything by herself.

Margaret willed down the sudden flood of memories; she had no time for them. "I'm getting you out of here," she told Geisler.

Geisler made a rude noise. "Maggie, there's no way I can pull myself out of here with just my arms, and you sure as hell can't carry me. I weigh twice what you do."

"Shut up. Think. We have rope."

"And two idiots instead of one." Geisler scowled. "OK. Gimme that rope."

Margaret took the fallen guideline and handed it to him. Geisler untied the end of the rope from the iron stake and looped it under his armpits. "Get up there and pull on the other end. Maybe you can give me enough of a boost that I can make it just climbing with my arms." He glared at her. "But if I start to pull you down, let go. It won't do neither of us any good if you fall down here, too."

"It won't work," she said. She knew she couldn't haul enough weight to help him. Then she saw it. "Try this. I pull on rope with lever. You guide with arms."

"What lever?" he asked.

"Beam from bridge. Move you a yard at a time up the side."

"Goddamn," he muttered. He sounded surprised, as though he understood what she meant and thought it might work. "OK, go."

Wordlessly, Margaret turned and faced the gully's ragged side. There was no time to stumble back to where she had climbed down; she started climbing, hoping that she would find adequate footholds and handholds as she went along.

She was barely right. Several times her hands and feet slipped when she misjudged her movements, but she managed to cling to the rocks. Ten minutes later she had pulled herself over the rim. The windblown dust was growing thicker, but she could still see well enough to work.

She went to the wrecked bridge, grasped the end of the wooden beam in both hands, and pulled. Its far end dropped into the arroyo, but she kept her grip on it and continued pulling. Inch by inch, she dragged it up and onto the ground. She laid it parallel to the fissure's edge, several yards back and with one end lined up with Geisler's location. She went to the iron stake and fumbled with the knot that held the line in place. Her fingers were clumsy, but after a few minutes she had the knot undone. She took the rope to the beam and tied it around the end.

That was her lever; now she needed a fulcrum. A large boulder set in the ground would have been conve-

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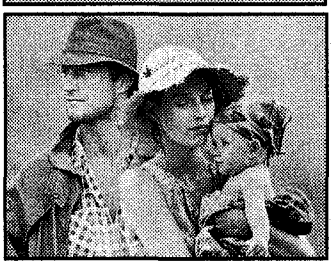

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nient, but the ground was too clear here. No matter. She took the iron stake in both hands and pulled it back and forth as she worked it out of the ground. It ended in a sharp point, and when she carried it over to the beam she was able to push it six inches deep in the ground alongside the beam. She picked up a rock in both hands and used it as a hammer, pounding the stake deeper into the ground. It went down two feet before it struck a buried rock and stopped.

It would have to do. Margaret looped the rope's slack around the end of the beam, then went to the other end and sat down by it, facing the gully. She put her feet against the wood and shoved. Reluctantly, the beam began to move, jerking a few inches at a time. When she pushed the horizontal lever as far as she could she got up and went to the gully. She looked over the edge and saw that Geisler was clinging to the rocks, a yard or so from the spot where he had fallen. He looked up and nodded tiredly; his mouth worked, but the wind drowned out his words.

Margaret went back to the beam. She pushed its end back toward the gully, then wrapped the newly-slackened rope around its end until it was taut. She returned to the other end of the beam, sat down, planted her feet against it again and shoved. She repeated the process over and over, while the wind rose to a howl and she felt dust and grit blast against her chin.

A fat raindrop splashed against her eyeplate, leaving a splotch of mud in the dust caking the glass. Another drop followed it, then another. An arm appeared above the gully's rim, flailed around and clutched the ground, and Geisler hauled himself into the open. Margaret picked up one of the canteens and took it to him. "Goddamn," he gasped after he had drained it. "Made it."

"Safe now," Margaret said.

He shook his head, then pointed to a heap of boulders a hundred feet away. "Let's get over there," he said. "When the rain picks up, this ground'll get muddy. Slippery. Things get bad enough, we'll get flushed into the gully, and then it's all over."

"Will it be dry over there?" she asked.

"No, but we won't get flooded out. Take the stuff over there. We'll need it."

Margaret picked up the canteens and carried them over to the boulders. As she turned back she saw Geisler pulling himself along the ground on his hands. He made good time, she thought as she retrieved the sack of food. The rain swiftly grew heavier, and Margaret began to slip as the dirt turned to mud. She ended up crawling the last few yards to where Geisler sat.

"Good spot," he said as she sat down next to him in the lee of a boulder. He began to open up his bedroll. "We're pretty much out of the wind, and we're on the downhill slope here, so we're protected from anything that washes down from farther uphill."

"Need my pack," Margaret said. Her recharger was in it, along with her sleeping bag.

"Forget it," Geisler told her. He nod-

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ded at the slope, where sheets of muddy rainwater cascaded into the gully. "You slip now, you won't stop until you go over the edge. So sit tight."

She was about to answer when light glared in the distance. "Lightning," Margaret said.

Geisler nodded and draped the bedroll over them. His lips moved silently, and she realized he was counting off the seconds until the thunder came. "Three miles off," he said. "Don't worry about the lightning. It'll hit higher up, on the hilltops."

"Good. How long will the rain last?"

"Beats me. Why? You goin' anywhere?"

"No." The rain washed the grime from her eyeplate, but the water swiftly turned her view into a sheeting blur. "Are you all right?"

"I'm a little banged up," he admitted. "I guess the trip is over. Think you can make it back to town without me, and get some help?"

"Yes."

"Good, 'cause I'm stuck here. Glad you saved the water and food. You'll need 'em for the walk tomorrow."

"Yes." We must still be in serious trouble, she thought, if he thinks I have to make a walk like that alone. But she could do it. And there was something else. "I remembered what happened," she said.

"Huh?"

"To Lydia. Alan."

Under the bedroll, he put an arm around her shoulder. "You going to talk about it, Maggie?"

"Not much to say," she told him. "What you sdaid about what happened was right. I don't know why I coulnt think of it before. But I remember some things now."

"Like what?"

"I missed Lydia's funeral. And Alan blamed me for everything. I let him because I wanted to believe it was my fault."

"Yeah? Why?"

She tried to think. "If it was my fault, it meant I could have done something to keep Lydia alive. A thing can't be your fault if you couldn't do anything."

Geisler nodded. "And you want to believe you could've saved the kid. If a whole hospital couldn't do it, how could you? And you can't live with guilt like that. If you don't kill yourself over it, it'll drive you nuts."

"I know. But I know I never thought about killing myself." She paused. "Or I don't remember thinking about it. I can't remember what any of it felt like, either. I don't think I felt anything then."

"You will," he said.

Margaret thought he sounded grim. It *was* grim, she thought. It would be like having surgery without an anesthetic.

The rain grew heavier, and between the noise of its pounding and the wind talk became impossible. The black clouds cut out most of the sunlight, and Margaret could barely see ten yards as the rain churned the slope into mud. Lightning struck closer and closer, and she wondered what the discharges might do to her helmet's systems. Her circuits were shielded, but the shielding could be

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overloaded. Then she heard Geisler's voice, half-lost in the sheeting rain as he said something about crispy critters. Margaret had to laugh at the reminder that the lightning could do something more overwhelming than damage a few circuits.

There was nothing she could do about that. She thought about Lydia and Alan instead. Reviewing her memories of the past—what, she wondered in surprise, ten months?—she felt baffled by the way her mind had worked. Things had happened, but she had blanked them out almost immediately. The frantic afternoon after they had received the flu shots, with Lydia falling down every time she tried to stand up and Margaret staggering around like a drunk, her voice growing slurred, while Alan packed them into the car and rushed them to the hospital. Lydia getting CPR in the emergency room, too late, while she was wheeled out on a gurney. Days on life support in the ICU. Alan taking an almost sadistic glee as he described Lydia's funeral.

She could concentrate on the memories now, but they remained as remote as a stranger's photo album. She wondered what she could have done to keep Lydia from dying. Not have her immunized? But there had been no way to know that she would react as she did to the shot. Get her to the hospital faster? Or a different hospital? The doctors hadn't known how to stop the damage from the shot; they didn't even know why it had stopped with Margaret when she still had her eyes and ears.

Alone. That had been the worst of it, even worse than Lydia's death. Alone, not just because her daughter and husband were gone and their apartment was gathering dust. Alone because she was living in a hospital, with friends and relatives limited to visiting hours. Alone because for the first month she had been unable to talk, unable to tell anyone how she felt. Unable to say that the therapists' well-intended monologues about grief and healing were torture.

The wind gusted, hard, and something cold and wet slapped Margaret in the face. Geisler swore and grabbed at the bedroll as the wind carried it off. It landed only a few feet away, but before Margaret could switch to her movement icons, the mud and water carried it downhill, toward the gully. Geisler huddled closer to her and tried to shield her from the rain. "I wondered when things would get interesting," he muttered.

"Trouble?" Margaret asked.

"You might say so," he said. He gestured to the arroyo, where the bedroll had vanished. "No blanket, no sleeping bag. We're gonna freeze tonight."

Margaret remembered how cold it had been last night. It might not cause her any discomfort, she reflected, but she could still die from exposure. So could Geisler. "Ideas?"

"This rain will stop in a while," he said. "The clouds should break an hour or so later. When they do, we can dry out in the Sun. Bein' cold and dry beats being cold and wet."

"Will anyone look for us before dark?" she asked.

"I wouldn't count on it," Geisler said. "We're supposed to be surviving

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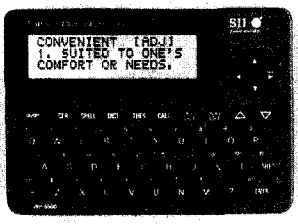

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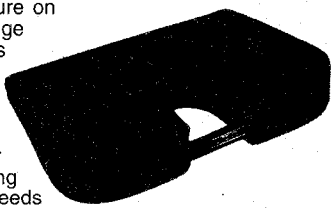

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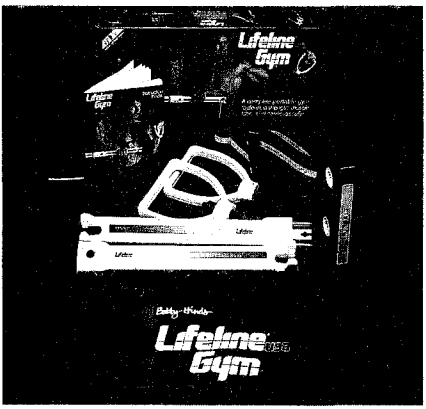

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on our own, and everyone knows I've made it through worse storms than this."

And they would need a helicopter to reach us, Margaret thought. Nobody was coming up here on foot, or in any kind of a vehicle, not until the ground dried out.

Margaret clicked on her time icon. To her surprise it was already four in the afternoon. She couldn't remember when the Sun had set last night, but she thought it was some time between eight and nine. That would leave only four hours or so of daylight.

The rain ended and the clouds began to break after a half-hour. Geisler dragged himself away from the rocks and out into the Sun. "Have to try to stay out of the wind tonight," he said, as he peeled off his jacket. He lay it on the muddy ground to dry. "You better get something to eat, Maggie. It won't hurt me to lose a few pounds, but you're gonna need your strength."

"Yes." She went to the bag and dug into it. She found a ham sandwich; the bag had leaked and it was soggy, but she didn't care. When she had finished she tried her modem again, with no luck. It seemed unfair. The phone company claimed that its cellular service covered every inch of the West. Well, that probably meant they had only covered the towns and roads out in the boondocks, as well as some of the more isolated tourist sites.

Geisler had said something. She remembered it now. She walked over to him. "You said my modem might work if I climbed a hill."

"It might," he said. "If you got high enough to get in the line of sight with a phone station, and if you're in range of it, and if the storm didn't knock it out." He looked around, then pointed uphill. "That's the only high ground you're going to reach today; maybe it's high enough. Gonna be slippery."

"Yes," she said, glad that he hadn't tried to argue. She looked at the slope, set her cursor on a fairly even stretch of ground, and started walking.

It was slow going. Her feet kept skidding on the muddy ground, and the top of the hill always seemed to be another hundred feet ahead of her, just beyond one more gentle rise in the ground. She tried her modem several times on the way up, without results. She kept telling herself that her luck would change when she reached the summit.

And that had better be soon, she thought as a yellow light winked on her display. The computer was warning her that her body was getting tired, with fatigue poisons building up in her blood and muscles, and blood-sugar levels dropping to a critical level. Fairly soon her muscles would stop responding to her inputs.

The top of the hill was a rise not much different from the last dozen swellings she had crossed, and she reached it two hours after she had left Geisler. It was like being on top of the world; she could see several roads and one highway in the distance, and a small town far to the east, beyond the hills. She clicked on her modem and entered 9-1-1.

A voice, female and mechanical, spoke in her ears. "We are sorry. Phone service has been temporarily disrupted. We are working to restore

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service. Please try again."

I could be up here all night, Margaret thought in frustration. She wondered how long it would take the phone company to get everything working again. Their repair service was supposed to be good, but everything was bound to take longer out in the boondocks. She would have to wait. At least that would give her a chance to rest.

She sat on a boulder and looked around. The skies were clearing rapidly and the evening Sun felt warm and good. The view to the west—a decade before her birth Buzz Aldrin had stood on the Moon and described the lunar surface as "magnificent desolation," comparing it to the high deserts of California. The Moon must be a beautiful place, she thought, if it was anything like this. Sun glinted off several small, temporary ponds like fire on a mirror.

Margaret was so taken with the view that she almost didn't notice the sound. It was a buzzing noise, low and distant. Not an insect, she thought, before she realized she was hearing the drone of a single-engine airplane. She looked, and after a moment she spotted it, a dark shape flying just above the western horizon.

Almost without thought she knew exactly what to do. She set her eyeplate to maximum reflectivity, and her view darkened as the plate turned itself into a mirrored sunglass. Then she began to nod her head: three fast nods, three slow nods, three fast nods. Over and over, to flash out a Morse SOS.

She kept it up until sunset, when she heard the roar of the rescue helicopter. By then the yellow warning light had turned red.

Margaret was sitting up in the hospital bed when Geisler walked into the room. "Fast," she said. "Thought it would take days for them to get you walking again."

"It did," he said. He stood at her bedside. "You've been out for two days. Exhaustion, mostly, and exposure."

"I guess I wouldn't have made it through the whole trip," she said.

He shrugged. "You lasted long enough to save both our butts, which is what counts."

"Yes. What happened after that plane saw my signals?"

" 'Plane'?" he repeated. He shook his head. "I don't know about any plane. Somebody on the highway saw a light in the hills, and when he realized it was blinking out an SOS he called the local cops. One of them remembered we were out there, and they called in a rescue 'copter. They homed in on the light reflecting from your helmet. That was good thinking."

"Thanks." She hesitated, puzzled. "Don't know where I got the idea. It just—" She hesitated again. Now she could remember a train of thought so rapid she had hardly noticed it at the time. Sunlight reflecting off water had suggested a mirror, which had suggested her eyeplate, and the sound of the airplane had reminded her of an old war movie in which a crashed pilot had used a mirror to signal a rescue plane. She wondered if her com-

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puter implant had had anything to do with it. She knew she'd never thought so fast in her life, not by herself.

Geisler couldn't know what she was thinking. "It just popped into your head?" he asked. "Well, who knows where ideas come from?"

Margaret didn't answer. I kept him alive, she thought as she looked at him. There was a way to keep him alive, and I found it, and he lived. If there had been a way to do that for Lydia, I would have found it. It wasn't my fault that I couldn't work a miracle.

". . . Talked to your doctors," Geisler was saying. "They figure that the computer was screwing around with your head, like you said. It tries to coordinate with your brain, you see, and every time it sensed things were getting out of control—like when you'd get a strong impulse to kill yourself, or when you got too upset over life—it stepped in and tried to cancel out the problem by feeding in its own electrical impulses."

"Keeping me alive," Margaret said.

"Not on purpose," Geisler said. "It was just protecting itself from overloading. There's a negative-feedback routine in its program, but nobody expected it to do this."

It kept me from thinking until I could handle everything, Margaret told herself. Until I knew Lydia's death wasn't my fault. Until I knew. . . .

The tears of grief and loss blurred her icons, making it impossible to speak or move. Geisler sat down on the chair beside the bed. He said nothing; he was just there, which was enough.

Until I knew I was no longer alone, she thought. ■

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—Bruce Chatton
(Submitted by Charles H. Hague)

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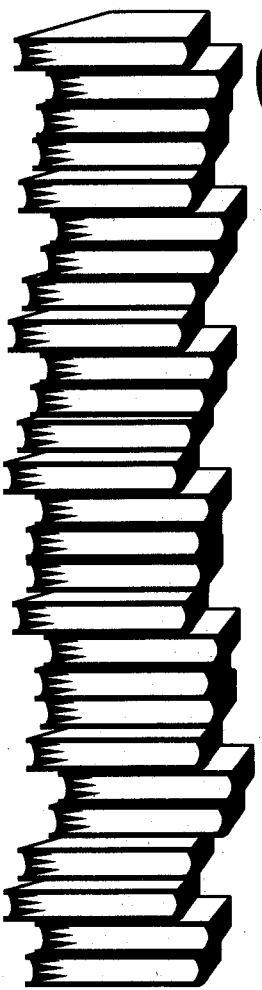

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THE SHADOW CAPTAIN

Starflight will create new gulfs between people—which some will still try to bridge.

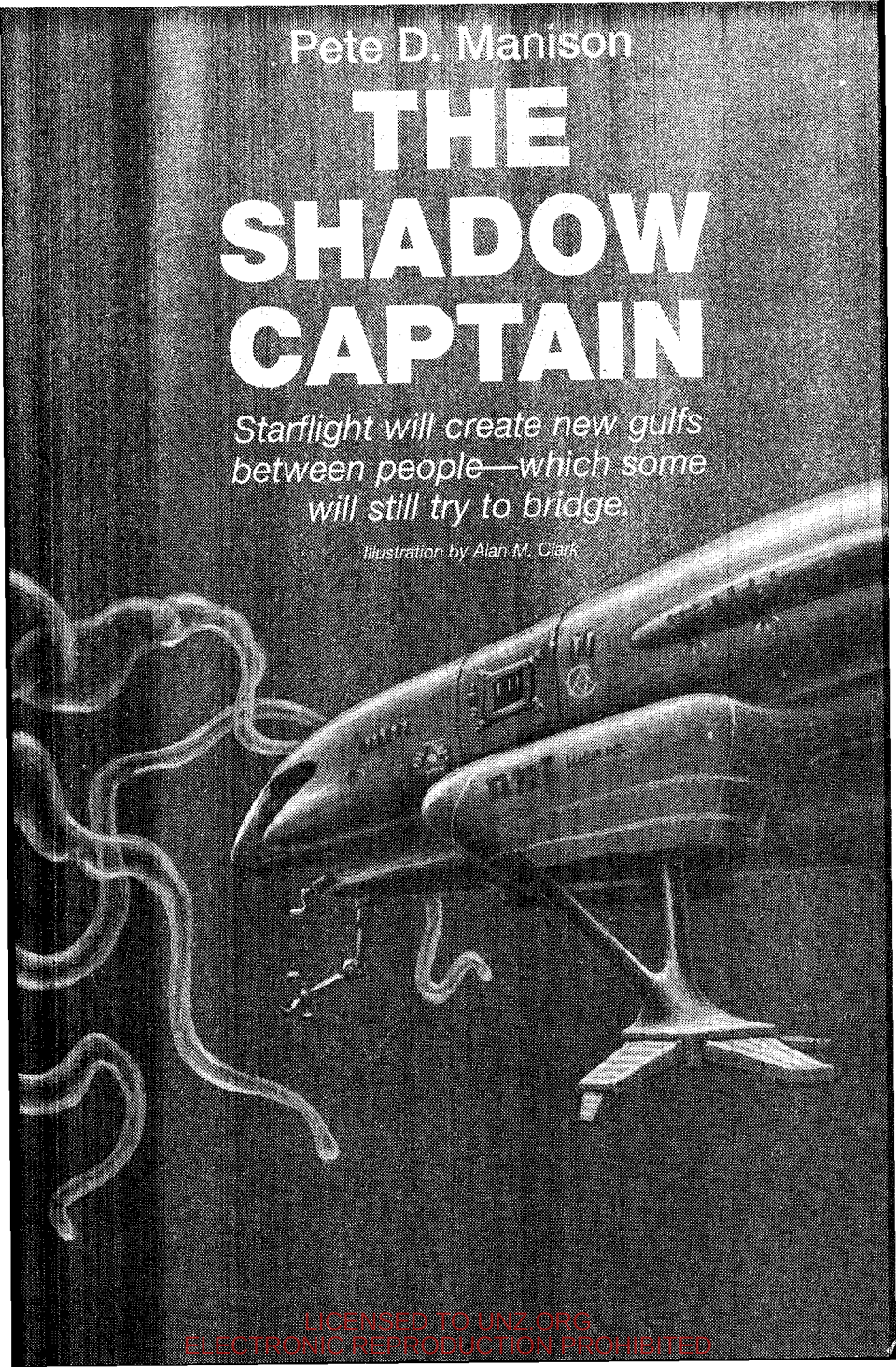

Illustration by Alan M. Clark

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Cara Wainwright had long since grown accustomed to the looks she got from the others, looks that said, "What can *you* offer a Captain that I cannot?" or, "You think you're better than us, you and your Captain," or, "Watch your back, sister. Perhaps I'll take your Captain from you." It didn't usually bother her. But today, out in the village and at the market, she couldn't help noticing the way they watched her, some with only curiosity in their faces, others with open hatred. It made her alone, loving a Captain. But that love was worth any price, and she hoped this was the answer those others saw in her eyes.

"Will that be all, honey?"

Cara focused on the vendor, a middle-aged woman who smiled at her in a way that made her feel not so isolated. This had been her home for twenty-seven years; perhaps she was imagining things.

Carrying her vegetables in a pouch over her shoulder, Cara left the market and started up the slow hill that led to the top of the high bluff. She could have bought a car, with all the money Rafael was always insisting she take. But she already felt conspicuous for the house he had bought her. And she liked walking.

It got harder all the time, Cara thought, harder to maintain the larger-than-life front that being the woman of a Captain demanded. But Captains *were* larger than life. They were the brightest and strongest of humanity's children. They alone could choose their destinies out among the stars. And only they could bestow that privilege on others.

Cara giggled suddenly. She must have been holding it in the whole time at the village without even realizing it. Now she couldn't stop, and she finally had to step off the path and set down the pouch and laugh and laugh until it had run its course.

He's coming!

The message had been brief, almost cryptic. *Be there soon. Tell no one.* But Cara had only seen that he was coming, coming soon, and then the feeling good had started and it had just gotten better and better as the days had passed.

And now it was the day.

Cara stopped when she reached the big oak that shaded the road from the hot midday Sun. Standing there and looking out at the sea, she remembered so vividly the way it had been, right here under this tree, the first time he had come to her. That seemed a magical time now, almost as if it had happened in a movie and not in real life. She had been overwhelmed that a Captain could take an interest in *her*. And then she had learned to know him as Rafael instead of Gregor or Captain, and she had known at once that her heart could never again belong to a mortal man.

"Hi, Cara."

"Warm this afternoon, isn't it, Cara?"

Cara turned. Two young girls from the village—she talked to them often and could never keep their names straight—walked past her on the path back from the market. She smiled and waved, and after they had walked on she saw them bend their heads together to whisper something and then

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draw apart, laughing.

She waited for the girls to get some distance ahead before she went on.

Clean house, cook dinner, get dressed, get ready, clean house cook dinner get dressed. . . . It was always the same, before her Captain arrived. Her thoughts danced faster and faster until they finally made her dizzy. And then the other thought happened, as it always did, and her heart pounded cold in her chest.

What if he didn't come?

But they said a Captain always kept his word.

Darkness took the sea as Cara stood on the balcony watching for fishermen in the bay. It had been outlawed, but she had seen boats almost every day. Whenever she could get a good enough look at one, she reported it. She wasn't sure if it did any good.

"Hurry home, my Captain, hurry home to me," she whispered, holding her hands together beneath her chin and swaying slowly from side to side. They were the lyrics of a popular song, and sometimes the tune was too bittersweet for her and she cried, but not tonight, not when he was coming tonight.

She tried to remember what she had thought of the Captains before she had fallen in love with one. The Captains ruled wisely and benignly—she had never doubted that. But sometimes she had wondered why they kept the gates of heaven closed to the rest of humanity. Were they hoarding the wonders beyond for themselves? Or were they protecting the world from the dangers that existed out there?

The bell chimed.

Cara started, then she turned. She took two steps before she froze, fear pulsing out from her heart to her whole body. Why was it always like this when he finally arrived?

"Cara?"

The hair on the nape of her neck stood up, and just then her legs came unstuck and she walked through the living room to the door, all the while chanting over and over, "OK, OK, OK, OK. . . ."

Then she was opening the door, and he was standing there, looking just as she remembered him in his navy blue uniform, tall and dark with black hair and beard, and bright blue eyes that spoke of sights beyond the imaginings of ordinary men.

"Cara," he said again, his voice softly cupping the name. She stood there staring at him for several seconds. Then he smiled, and without conscious thought she flung herself at him and hugged him so tightly her arms ached.

"Rafael," she whispered, "you're here."

She felt his hand in her hair. "Yes," he said, "I'm here."

Cara drew back slightly, looking up at him. Her Captain was a tall man, as Captains tended to be, and he was solid and strong. As he looked down at her now, his hair brushing his shoulders and the half-moon insignia that unnecessarily signified his status, she thought as she often did that this was the most lovely creature built by God, that perhaps it was envy that had made Him create so few.

"I missed you, Rafael. I never

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stopped missing you."

He smiled, that bright beaming smile that he brought from the sky just for her, but now there were shadows at the corners of his mouth, and his eyes looked deep into some space within her that she hadn't known was there.

"Cara, there's something. . . ." He stopped, looking down. It was the first time she had ever seen him—seen *any* Captain—show uncertainty, and for some reason it felt like a cold hand squeezing her heart.

"Don't," she said, leaning into him again. He rocked her head against his chest for a while, and Cara thought that this must be how Siva felt as he danced the dance that created the Universe one moment to the next. Only Siva's dance was eternal, and Captains never lingered so long.

"Sometimes I thought you wouldn't come back," she whispered into his ear. His hands took her chin and gently tipped her face up to his.

"I couldn't go on without stopping to see you," he said, and then his lips on hers awakened something in her chest that burned with an intensity she had never felt. She tugged at his hair as she felt his strong arms encircle her and lift her from her feet. After that it was all like a movie again, or like a dream, as he carried her out to the balcony and made love to her on the oaken deck with the sound of the surf pounding on the rocky shore below. It wasn't loud enough, though, to drown out Cara's cries of delight as he brought her first to one climax and then to another.

She must have slept for a while after that, because when she opened her eyes the Moon had risen. He'd found a blanket and wrapped her in it, but when she reached out, he wasn't there. She turned her head.

Her Captain stood looking out at the sea, his knuckles white where they gripped the balcony railing, and in the light of the Moon Cara could see that his face glistened with tears.

In the morning, gulls greeted the two solitary figures as they walked arm in arm down the beach. Cara felt soft and quiet and perfect, her head on his shoulder, his arm around her waist. The wind made his hair wild, and the way his eyes watched the watery horizon, almost searching, made her wonder what it was he saw when he looked out there.

"The sea is our soul," he had told her on his first visit, "and the stars our destiny." She wasn't sure whether it was a poem or not. Whatever he said was poetry enough to her ears.

Two dolphins leapt out of the water not far from shore, mist spewing from their blowholes, and turned in unison to dive back beneath the waves. She could almost feel his awe at this sight as he took a sudden breath and held it.

"Beautiful," he murmured. "I must never forget."

They walked on for a time before he gestured and they moved toward a trio of boulders that lay propped up against one another not far above the shoreline. In the shade, small animals rustled as they approached but were gone by the time they got there.

"It's a perfect day," Cara said, turning to tug on his hands and marvel at

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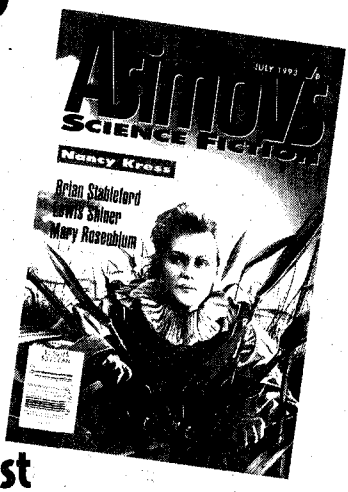

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the way the sunbeams brought out such strength in his face. Other girls dreamed of Captains, as she once had. They watched them walking in the streets of the village, on their rare appearances, those girls who giggled and pointed, their pink nipples straining against their blouses, and perhaps they went home telling each other stories of how it would be to love a Captain. What did they know? What *could* they know of this kind of love?

"Rafael."

They'd been hunting sand dollars, and the basket she carried smelled of kelp. He grinned as she went through the collection, separating the broken ones and discarding them.

"I brought you something," he said.

She looked up from the basket. He was smiling, his eyes flashing as they had the night before. He reached into his pocket and pulled out a small box.

Cara's heart pressed against her throat. Her hand trembled as she reached out. He opened the box. She sighed, more surprised than disappointed.

"It's called a Rohn stone," he said.

Cara reached out and picked it up. It was a sphere about two inches across, and it glowed a milky blue in color. Its light was very bright when she held it cradled in her hand in the shade of the boulder.

"One of a pair," he said. He pulled out another such stone, which was attached to a chain he wore around his neck. "The brighter they get, the closer together."

Cara looked at the stone again. "Magic?" she asked.

He smiled. "Natural tachyon emitters. They resonate when brought into proximity."

It only dawned on her slowly. "Then I'll always know when. . . ."

They held each other for a long time, sharing the cool air and the sound of the wind rushing through the grasses that lined the hillside.

"Last night, you said something." Cara spoke softly, not looking at him until after she had begun. "What did you mean?"

She was wearing a red T-shirt tied off above the midriff. His windbreaker was unbuttoned down the front. As he held her tight she could feel a thin stretch of his exposed abdomen pressing against her own bare skin. His skin was warm and slightly moist over hard muscle where it touched her, and somehow that touch was the most sensual feeling she could imagine, even more so than the ways he had pleased her the night before. This was more mysterious, like him, with so much more left to the imagination.

To love a Captain was to love a shadow, it suddenly seemed to her. For who but a Captain could ever fully know what it *was* to be a Captain?

He had not spoken, and she feared she had offended him. One never asked things of a Captain. Favors were bestowed. To ask was unthinkable. But the message, the pain beneath the joy in his eyes. . . .

"Rafael? Is it someone else?"

He looked at her blankly for a second, as if that were the last thing he had expected her to ask. Then he laughed. For a whole minute, he laughed, that robust series of explosions from deep inside him, his head

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thrown back and his mouth open wide, that had first made her fall in love with him. For a man to live so fully each moment, for him to feel so intensely alive every second of every day. Was that the gift of being a Captain? Or was it just Rafael?

Finally he looked down at her again, smiling. "No, my love, it's not that. It's not that." By now his laughter had faded to a smile, and as he spoke even that faded until he was staring into space, his expression vacant.

"There's something out there, Cara. It . . . wants something from me."

She waited, listening hard, searching between the words for something that would tell her more. Then the moment passed, and her Captain took her hand and pulled her with him as he moved away from the shade of the boulders.

"Let's take the boat," he said.

The water was choppy, and not many boats were braving the high wind that often came in the late hours of the afternoon this time of year, but Rafael handled the catamaran with ease, taking them far out into the mouth of the bay where you could see forever until the world ended and the sky began. Only the horizon, dotted with agriforms and roving eco-patrols told her that they weren't alone on all the seas. Captains loved their worlds, cherished them like precious jewels. It comforted Cara to know that what intrusions she could detect existed to maintain the ocean as near to its natural condition as possible.

"It's so simple," he said once, cutting the boat into the waves just so, sending it flying from the crest of one to the crest of the next. "Like skipping stones."

She wondered how it was out there, what rudder he used to guide him through the sky, what sails could run on starlight and dreams. She asked him, but he only laughed and held her close as he trimmed the sails and took them even farther out. Finally, when the lighthouses alone were visible as dull gray blobs on the ocean horizon, he brought the boat about and lowered the sails.

They drifted, watching the Sun set.

"It's so good to be here," he said quietly after a few minutes had passed in a silence that almost lulled Cara to sleep. "I wish it could last forever."

There it was again. Never before had her Captain's voice held such pain. She lay beside him on the deck, and now she turned toward him and propped her head up with one arm. "It *is* forever, Rafael. Each time, it's forever."

He stared up at the darkening sky, his gentle smile tinged at the edges with a regret so bitter that it stung in Cara's eyes. Still, he told her nothing, and only one incident gave her any hint that her Captain was not the same man she had known on his earlier visits.

They had just rigged the lights and started in when the boat entered a large school of jellyfish swimming near the surface. They glowed translucent blue in the lights of the boat, their bodies pumping and their tentacles floating like red hair all around them.

"Gods!" Rafael hissed. He hoisted the mainsail and turned the boat into

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the wind with such abruptness that Cara was nearly knocked overboard. Only when they'd traveled far from the jellyfish did he turn again toward shore. His face glistened with sweat, and she was certain she saw his hands tremble as they pulled on the lines.

"You're still working at the institute?" Rafael asked from the kitchen.

Clad only in denim cutoffs and a sweatband, he was preparing dinner while Cara sipped wine and looked through the album of holograms he'd taken on an iceworld somewhere in Canis Major. The holograms showed hexagonal crystalline structures like snowflakes but a million times bigger, bigger than mountains.

"Yes," she called. "But they promoted me to supervisor of my department."

"Congratulations! You know, if you applied—"

He stopped, because he knew he didn't have to say the rest. He'd asked her about it on each of his visits. There were as many female Captains as there were male ones. But Cara shook her head now, as she had before. On every world, young men and women aspired to be Captains. They put themselves through the training and then the tests. It was a five-year investment just to reach the point of being chosen for the program or passed over, and the vast majority were always passed over. Few indeed were selected to become Captains. And the Captains rarely commissioned a new starship to be built.

That would change us, she thought, holding the wineglass to the light and watching the burgundy reflections dance on her wrist. Why didn't he just ask her to go with him? she wondered again, as she always did. But he didn't, he never did, and it wasn't a question one asked *of* a Captain.

Dinner was delicious. Rafael had prepared grilled salmon and wild rice, a simple meal but in his hands a gourmet's delight. For dessert they nibbled fresh berries collected from the nearby fields. Then they kissed, their lips purple from the berries, and for a while Cara pretended that everything was normal.

"On Holder's Relay they fry airfish in volcanic vents that give the meat a flavor like bacon. And they live on the eggs of dinosaurs who change color with the seasons." His voice took on that quality whenever he spoke of the wonders he'd seen, soft and wistful and full of hidden tones and possibilities. But it always sounded like he was leaving out most of it, like there were no words to express the things he found out there among the stars.

"Rafael," she asked later, after the Moon had risen with Cassiopeia low in the north, "what was it you were going to tell me?"

He looked at her in that way that sometimes made her feel like a small child. "I have to go away again," he said, his tongue so nimble on the words that killed her. "Longer than before. Maybe a lot longer."

She listened numbly, remembering how he had spoken similar words before. But she could tell at once that it was different this time.

The silence stretched out, and Cara held her breath. When he didn't speak at all, she reached out and took one of

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his hands in both of hers. She lifted it to her mouth and lightly kissed his palm. "Whatever it is," she murmured, "you can't leave me not knowing."

His eyes flared quickly. Not since his ascension to Captaincy, perhaps, had another human being told him what he could or could not do. But then his face gentled. When he looked at her again, his eyes sparkled with a forced amusement that seemed to cover something deeper. "Thank you, Cara. Thank you for being the strong one. I think I lacked the courage, alone. But if I hadn't told you, I would have regretted it forever."

She stared at him, knowing her astonishment was plain on her face. The Captains didn't feel *fear*.

Then he told her the story, and she found herself wishing he had lacked the courage after all.

Drifting easily into orbit of the new world, careful not to disturb the lifeforms that have already been detected on the surface. Gregor takes the scout craft on manual, easing his speed until the transition is complete. Farprobe 7 *hangs in geosynchronous orbit above an island whose offshore reefs reflect the greatest concentration of biomolecules. But it isn't only this that has drawn him here, out of this wide system of asteroid belts and still-forming planetoids. It's also the dreams. It's mainly the dreams.*

He reports none of this back to the mother ship, Paracelcus. *He's a Captain, and* Paracelcus *is his ship, and they can hear what he wants them to hear when he wants them to hear it.*

He lets the landing computer put him down on the island.

All around, green oceans roil to the horizon. The planet has a single large moon, and the tidal effect is very pronounced. An Earth boat wouldn't last five minutes out in that, even if the air were fit to be breathed.

"Computer," he orders, "prepare probe for undersea mode. And scan biomass."

"Probe ready," it answers momentarily.

"And the biomass?" he asks.

"Scan underway. Available biomass for scanning is seven point nine trillion tons."

"How much?"

"Seven point—"

"Captain's interrupt. Scan a small slice of the biomass and report findings."

"Reshuffling data. Analysis complete. Twenty-two thousand plant and animals species recorded."

Gregor feels the thick hair of his forearms standing on end. But how stable is it? Has there been time?

"Computer, display the most highly advanced animal life-form."

The diving mode instructional screen drops off, replaced by a 3-D of something that makes Gregor gasp, his eyes widening in wonder, as he falls back into his seat. It's huge—bigger than a humpback whale. But its shape is round, its body undulating, and it trails long tentacles behind it. It looks almost like a jellyfish, but the internal structure of the body is something never designed for human eyes to comprehend. Air bladders puff out along the outside—that much seems familiar. But within

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these lies a membrane full of tiny diamond-shaped holes, and underneath that are numerous tiny organs—some brown, some black and some red or green or blue. They all pulsate, and though they vary in size and shape they all have tubes that emerge from the creature's body, pulsing with the passage of fluids through their lengths, and curve up to merge with the head. The head itself is as big as a living room, and inside the transparent membrane is something that looks like sand, colored in swirls from all the tubes that feed into it. The sand shifts and turns in living cyclones inside the animal's head, sometimes in a frenzy of activity like a Martian dust-storm, sometimes slower and softer, like it's dreaming.

"Look at that brain capacity," Gregor says. His voice echoes off the walls of the probe. "If that is *a brain." But he's laughing, his eyes moving up and down the length of the creature's body, his smile making him look like a fisherman who's finally gotten the one that got away.*

He sleeps three hours, and then he takes the probe beneath the waves.

"I made contact with them almost at once," Rafael said. Cara lay with her head in his lap looking up at his face as he spoke, and the depth of his voice made her imagine twisted shapes rising out of the alien sea, strange four-winged birds circling overhead, and ghostly sails billowing from the decks of oddly-crafted ships.

"They must be very far away," she murmured, looking past his face to the stars that sparkled across the sky now that the Sun had set.

But his voice was cold. "Not far enough."

In the probe's cramped interior, Captain Gregor programs the ascent sequence. He has already inflated three tug-alongs and filled them with biosamples, and now the probe is at maximum capacity and he's almost ready to take it back up to orbit.

Almost.

The Hur'klee are fiercely territorial. They have conquered all the lower species, as humanity has on Earth, and the climb to the top of the planetary ecosystem has left them just as aggressive and inquisitive and possessive. Gregor fears for his life until he realizes there is nothing he possesses that could be of any value to them. Only his knowledge.

Three weeks he has spent among the Hur'klee, and now they have asked him to participate in a ritual before his departure. He hopes it will shed more light on their culture than the dances he has recorded. That is the only way they tell stories—by dance—and it takes a Hur'klee most of its eighty-year adolescence to master the nuances of the medium. The computer has made rough translations since the first week, but they're literal translations only; good enough for rudimentary communication but insufficient for the decoding of myth and custom and law that weave the fabric of a culture.

Gregor sighs. Such is the fate of a Captain. Always to discover the new and the alien, never to be given time

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to learn what strange truths pulse beneath the glistening exteriors of the lifeforms and the artifacts that pass so fleetingly through his hands.

At the ceremony, he meets a Hur'klee named Tur'taya. This is a male, Gregor observes, and somewhat larger than the norm. Tur'taya has been a dark presence lurking in the background through much of Gregor's visit. Others of the Hur'klee avoid him. They seem to fear him, and whenever he draws near, their minds close up and Gregor's translator goes offline.

Now a large school of them has encircled Gregor and Tur'taya. Tur'taya extends his tentacles out in every direction until he's like a starburst filling the ocean, and even through the probe's windows it is a sight that makes Gregor think of hot gasses rushing into some primordial sun that's about to ignite. He holds the probe steady, drifting with Tur'taya. It's only when he feels the gentle wind blowing through his mind that he remembers the dreams.

Someone calling, someone searching, someone cast adrift among the stars. And here, others crying out, their voices not quite so strong, probing among the waves for rocks and predators and dangers that lay hidden behind the veils of the sea. But some, the strong ones, projecting themselves farther, searching along other kinds of horizons.

Now Tur'taya fills Gregor's being with his alien thoughts—flashes of color and flavor and other things too hot and fast for Gregor to understand. He can feel Tur'taya's mind encircling his own, but that mind is strangely vacant. Gregor twists in the Mindtouch. Ripples sweep out through the medium that connects them.

[Listen,] *a voice seems to say.*

And then he hears them. Six, nearby—voices on the waves. And through them, thirty-six others, slightly fainter but in solid contact. And beyond, by multiples of six, until the whole superpod floats there in Gregor's mind, each a tiny part of this web of their collected minds.

And Gregor senses it at once: hunger. The Hur'klee have spun a vast mental framework—so vast that even all they have learned fills only a tiny fraction of it. It is a mind that needs more than it can reach, one that has grown twisted and dark as it has been forced to feed on itself.

And loneliness. Nowhere else is there a mind to match its own.

The images stop. Blackness engulfs Gregor's mind, but then he feels it return, the grasping pressure of the Mindtouch feeling somehow different this time. He understands at once that it is just Tur'taya now, his mind alone, and that there is something he desperately wants.

Mindtouch.

Tur'taya wants to enter Gregor's mind. He wants to probe for himself this new curiosity that has drifted into the range of his senses.

Gregor feels his body lay back in Farprobe's *command chair, senses that he is breathing through his mouth as if in a deep sleep. But he's awake, and Tur'taya is here, experiencing the sensations of this body, of this mind, and then moving on to*

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deeper places that Gregor is scarcely aware exist within him.

Tur'taya finds Cara.

Here she is, a living entity in Gregor's mind. More than a hologram, more than a memory, there is an entire universe encoded here through the eyes of the Captain's love for the woman who waits for him even now on some lonely shore far from these waters. She's lovely, swimming and running in the surf, her chest swelling and shrinking under the exertion. And then he's tackling her, the two of them rolling at the edge of the waves. Tur'taya pushes the contact deeper, until it isn't about people any longer but about two candles flickering in the darkness, clutching each other close for a time and then parting. Always stronger when they are joined.

Tur'taya experiences all of this, which is so much of Gregor that he cries out against having it glimpsed by another mind.

And then Tur'taya cries out as well, his bellowing wail thundering through Gregor's mind and bringing the Captain to the edge of madness. He feels Tur'taya's body, for an agonizing moment, as if it is his own. And then he understands. Within the alien's mind, splintered into shining fragments spread throughout his own darkness, hang other minds as well—others of the Hur'klee and of the lesser related species that swim these waters.

That, he learns, is how a Hur'klee male loves. It loves through consumption, by making the object of its love a part of itself. And he sees through the eyes of the beast, sees the long and lonely search for something new. Tur'taya is ancient. He has absorbed every mind and soul he has found, yet his hunger remains, his desire unsatisfied. Nothing is new; nothing is different.

Until now. Through Tur'taya's mind, Gregor sees himself—so strange, his frail and tiny body. Yet so beautiful and new. This one is male, *he feels Tur'taya think. Then there's a tentative tug at his soul, a hungry clutching, then the blessed release of rejection.*

No, a male will never do.

But in this tiny mind, Tur'taya has glimpsed another.

Now Tur'taya's mind slowly withdraws from his own, and the Mind-touch fades to only a remembered tingle. Gregor takes the probe's controls in his hands and jerks them savagely. The probe begins an emergency ascent.

But Gregor knows that it is already far too late.

"Forgive me," he said, stroking back a lock of hair that had fallen across her cheek. "I felt that thing fall in love with you, Cara. It happened in a heartbeat, faster than that. The same way it did for me. The same way." His voice trailed off again, and he stared into space as he had before. Cara trembled in his arms until he rubbed warmth back into her.

"It was a survival mechanism," Rafael said. "The jellyfish that can leave its body to spot approaching danger has that much more chance of living long enough to procreate. And it can find food the same way. Soon the

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jellyfish that *can't* project are starved into extinction. And the ability just keeps developing, spiraling higher, until the range is almost limitless. Until it can reach out into space and touch the stars."

Cara stiffened. "You mean it can . . . leave its world?" Something in his eyes gleamed cold and terrifying now, and if he didn't speak she felt she would go mad.

"Not in its body, no. But it can Mind-touch. And Cara, it loves you. As deeply and completely as I do. It found your perfect image in my heart, and its hunger was too great for its mind to control. You may have been alien to it, but you were beautiful, different and new. It wants you. It *needs* you. And its love is something too terrible to contemplate."

She was sitting up now, watching his face for the tiniest indication that he knew. The dreams—she hadn't wanted to mention them to him, hadn't wanted to even think of them.

"He's coming for you, Cara. Tur'taya followed me into space, his mind chasing my ship and searching for the signature I had carried inside me, the signature of your soul glistening like a pearl inside his sickly shining head. All he can think of now is having you, of consuming you, of swallowing all the bits of you until they are nothing but bright spots scattered inside his greater darkness."

She was sitting now, her legs curled underneath her. Somehow, she still felt safe, as long as he was here. But now she felt something cold, too, something that searched for her through the stars, its mind sharp and untiring while its body drifted in alien seas and dreamed the stolen dreams of their love.

"You came back," she said a little time later. "You came back to me."

His fists were balled up in his lap, and now he was staring at the ceiling. "God forgive me, yes. I couldn't launch out there without seeing you one more time. And I think I have an answer, too. Last night while you slept, I took an imprint of your brainwave patterns and your body's electromagnetic signature. If I'm right, I can use a tachyon emitter broadcasting those patterns to lure Tur'taya away from Earth, far out into space, somewhere so far away that he can never find his way back."

"What makes you so sure it will follow you?" Cara heard her own voice ask, strangely distant.

Rafael's eyes turned inward, questing, a worried frown on his brow. "I wish I *could* be sure," he finally answered. "During the voyage to Earth, I studied the Hur'klee—their sensory organs, the characteristics of the tachyonic 'selves' they project into space. I'll amplify the recording and broadcast it from the ship as I travel. I can only hope that's enough to fool him, to drown out your true mind-print and make him come after me instead."

"And then?" she asked, reaching for his hand, hesitating.

Rafael sighed. "And then it will be done. Tur'taya will have lost."

Cara listened for long seconds, sensing the lie but not knowing what it meant. Then she took his hand.

"Take me with you," she said.

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Rafael looked at her, and for the first time she saw that solid wall that is the will of a Captain. This was the side he projected to others, but never to her. This was the unyielding barrier no mortal could hope to puncture.

"I can't, Cara. I can flee from this thing, and maybe I can outrun it if I push the tau far enough. I've commandeered the fastest available ship. But this is *my* responsibility."

"We'll take our chances," she blurted. "Don't leave me like this!"

She expected anger from him. It was actually a crime to speak to him as she had. But he only smiled sadly, smiled and shook his head. "Now I know why I love you, Cara Wainwright. It's because you alone see me as a man, not only as a Captain. That is the greatest gift you could have given me."

"A going away gift?" she asked, feeling hot pressure behind her eyes but not wanting to give him the satisfaction of seeing her cry.

"Cara, I couldn't go on living knowing that I'd brought you into danger. And every minute that I remain brings the danger closer."

She sniffed, pushing herself back into the couch a body's width away from him. "So that was the only reason you came back, for the recording?"

His eyebrows drew together. For a moment his blue eyes looked almost gray, clouded with thoughts his mind was too disciplined to reveal. Then they were clear again, and Cara knew in that moment that she had lost him.

"I came back for the recording, Cara, yes. That is the best way for us to remember it."

It was raining that morning, a cold rain that blew off the ocean and pattered dully against the roof. They stood on the front porch. His cab had hovered to a stop a few minutes earlier, its robot driver patient as the hills when Rafael told him to wait. Huddling under the edge of the roof away from the rain, they clung to each other and spoke in deep gazes of how it might have been, and also of how it was, which in the end is always more important.

"You showed me how to live my life for every moment," she said to him, and that made him smile. But inside, she was crying, and even the terrible thing that stalked her seemed trivial beside the fact that she was losing him, she was losing her Captain, that he was flying away for the last time and neither one of them had the courage to admit it.

"Maybe I'll make it back by Christmas," he joked, wiping the raindrops from her face. "She's a fast ship."

Cara nodded once, but her eyes dropped from his face, and she knew better than to believe in dreams. Her whole life had been a dream since meeting him, and now the dream was over, and the waking Sun was harsh and unforgiving.

"Remember me," she whispered. She lifted up onto her toes and kissed him. His lips were moist but firm. His mouth spoke of a person inside him that was no Captain, no ruler of worlds or traveler among the stars. It was just him, just Rafael. And then she knew what all those girls in the mar-

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ket and on the streets could never know. To love a Captain was simply to love, and there was really nothing more to it than that.

"I'll watch the stars every night," she vowed. "And every time I look, I'll know that I'm looking at you."

Worry creased his face, and she wasn't sure what he was thinking. She started to speak. He shook his head and turned away. Then he was moving, a stiff shadow cutting through the rain toward the cab, and she was watching, watching as the door slammed shut, watching his face in the window until the rain reduced it to an oval of warm colors and then to nothing at all, as the cab disappeared into the rain.

Cara went inside. After that, whenever it rained, she felt that same hot pressure behind her eyes, and sometimes she cried, and sometimes she laughed at the remembered joy of what it had been to love a Captain.

Years passed, and Cara handled the transitions of time with what grace she could, always living in that tiny village by the sea. Often she would sit on the balcony at night, watching the sea and the stars and wondering. Had Tur'taya found him in the end? Then why hadn't it come for *her?* And if Rafael had prevailed, why was there never any sign from him? Did he have to go so fast in his flight from its alien love that when he slowed down again her life had come and gone, leaving only the buried ruins of the village to remind him of her?

Only one clue ever came to her, and it didn't come until seven years later. She was sitting alone at an outdoor cafe when she spotted a man watching her from a shop on the other side of the courtyard. It was too far to make out details, and he was dressed in the common garb of the townfolk, but something about the intensity of his eyes beneath the shadows of his hood tugged at her. He radiated turmoil, as if two powerful forces warred within him. She got up from the table and paid for her meal, but when she turned back he was gone. It never happened again, and she was never certain it had really been him. The dreams had long since vanished. Only one tangible remnant of her Captain remained.

When she got home after the encounter, Cara went immediately to her jewelry chest and opened it. There, hanging from its chain, was the stone he had given her. It was glowing strongly, so bright it lit up the whole room. That glow brought it all back to her, how it had been to love a man who walked among the stars, the thrill of indescribable excitement but the fear that was almost as strong, that was sometimes stronger.

For the next few nights, the stone shone dimmer and dimmer each time she looked at it, and one day it ceased to shine at all. But Cara remembered it. Even after she had married a man and borne him two children, she remembered. ■

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Robert A. Freitas, Jr.

THE FUTURE OF COMPUTERS

Progress Report on Our Friends in the Mechanical Kingdom

This year's big supercomputing conference, "SuperComputing 95," to be held in San Diego, CA in December 1995, features what sponsors are excitedly calling the Teraflop Challenge. This is a contest to see if supercomputer designers can prove that one of their latest machines can compute at the peak speed of one trillion Floating-point Operations Per Second (FLOPS). It's an even bet someone will win.

One teraflop. That's One Human, folks.

Yes, I know you need software. Also, the processing capacity of the brain has not been reliably determined. But a fair estimate is that the 1.5 kilogram organ has 10^{10} neurons with 10^3 synapses firing an average 10 times per second, which is about 10^{14} bits/second. Using 64-bit words like the largest supercomputers, that's about one teraflop.

Figure 1 charts a century of evolution in data processing power based on more than 100 mechanical and electronic computer systems. I started with Moravec's numbers (Ref. 1) and added new information for machines built since 1987, various robot systems and NASA computers I'm famil-

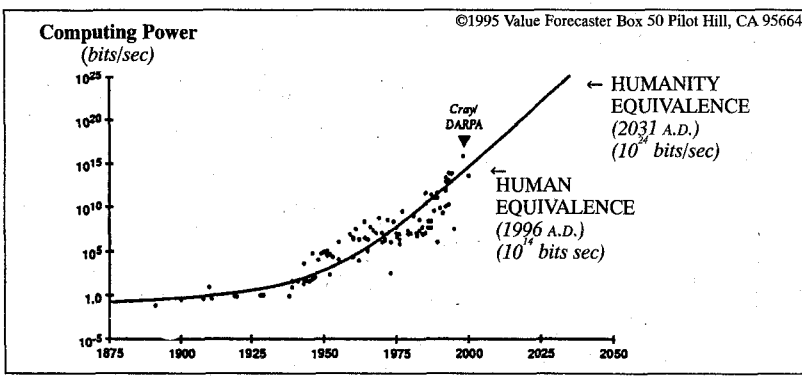

Figure 1. Rise in Data Processing Power of Computer Systems

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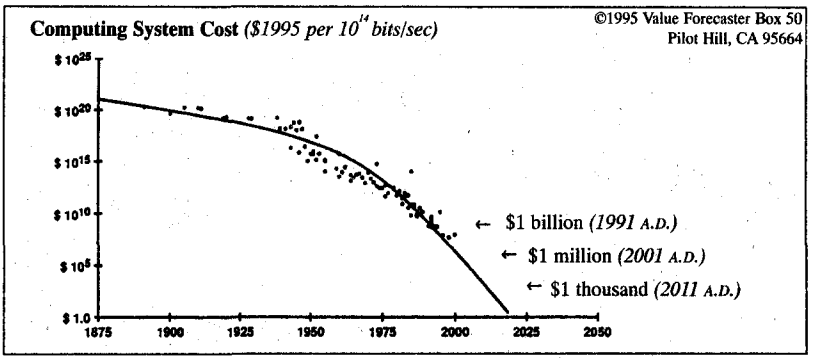

Figure 2. Cost of Human-Equivalent (Teraflop) Computer Systems

iar with, and a few mass-consumer products we have around the office. I also included a few projected machines: The 9-teraflop Cray/DARPA (Defense Advanced Research Projects Agency) machine, due in 1998; the 1-teraflop NEC Super, due in 2000; and the proposed 2-teraflop upgrade of Thinking Machines Corporation's Connection Machine-5, which the company claims could be assembled by 1996 using existing technology for a stiff $100 million fee.

Figure 2 shows the declining cost of teraflop capability in constant (inflation-adjusted) 1995 dollars. According to these data, by 2001 the price of a Human-Equivalent Computer (HEC) should fall to one million dollars, well within the research budgets of most universities and research labs. The 21st century will open with an explosion of intensive experimental and development work to create "man-in-a-box" software. By 2011, teraflop systems should cost only $1,000 and will begin to be incorporated into homes, cars, and high-end household appliances. Astonishingly, Figure 2 suggests that by 2021, HECs will cost a mere $1, which means they'll start showing up in children's toys and magazine inserts. Thus, the chart tells us that just 25 years from today, artificial intelligence (AI) may become "too cheap to meter."

FASTER CHIPS

To keep the progression going, we need faster and faster components. Intel's successor to the Pentium, the P6 chip, clocks in at 133 million ops/sec. Texas Instruments's new superchip, the MVP, handles two billion digital signal processing operations a second (a 0.002 teraflop device). Using conventional silicon technology, if DRAM (Dynamic Random Access) memories keep doubling their surface density every two years, as they have for decades, then by 2001 we'll have a gigabit storage chip, pushing silicon near its ultimate limit. (At 0.1-micron, about the wavelength of an electron, silicon transistors break down as electrons start tunneling through their switchgates.)

Then what? Mark Johnson at Bell-

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core in Red Bank, New Jersey, proposes building computers with "bipolar spin switches" (Refs. 2,3). Johnson's switch, which uses the direction of a magnetic field to control an electric current, is a sandwich of two magnetic alloys and a film of gold. The first magnetic film polarizes the spin axes of electrons carrying electric current in the adjacent gold layer. A population of spin-polarized electrons builds up in the gold, causing a "spin bottleneck" effect. The second magnetic layer opens the switch (allowing electrons to flow) when its magnetism parallels the first layer's, and closes the switch when the magnetism is reversed. Unlike semiconductor transistors, the performance of all-metal spin switches should continue to improve well below the 0.1-micron silicon limit.

A better-studied alternative is the Josephson junction, a niobium/metal-oxide superconducting electronic switching device first investigated by IBM in the 1960s. A Josephson logic gate operates much faster but differently than a semiconductor gate—it switches like a latch and does not return to its initial state after the input signal is turned off. By comparison, a semiconductor gate changes state only while the input signal is applied.

The first stable, high-quality Josephson junction was fabricated in 1983. By 1989, Japanese researchers at Electrotechnical Laboratory in Tsukuba had constructed a prototype 4-bit superconducting computer named ETL-JC1. This was the first machine to execute computer programs installed in a Josephson ROM (read-only memory) chip with a Josephson central processing unit and RAM (random access memory) chips. By 1990, the Japanese group advanced to an 8-bit microprocessor with 6,300 gates operating at 770 MHz clock speeds (Ref. 4).

Konstantin Likharev of the State University of New York at Stony Brook is pushing the technology even further using a new kind of gate logic called Rapid Single Flux Quantum (RSFQ) logic, that promises to overcome drawbacks of earlier strategies. Already, simple RSFQ circuits made of the low-temperature superconductor niobium are running at speeds of 50 billion cycles per second, 1,000 times faster than Intel's Pentium and 100 times faster than the quickest silicon devices. "Improving the technology," says Likharev, "offers hope to achieve speeds of around 300 billion operations a second. Energy consumption is a million times less than typical silicon memory cells."

Optical computers are another option. Alan Huang and colleagues constructed the world's first digital optical processor in 1990 using Symmetric Self-Electrooptic Devices (S-SEEDs), computing elements first invented at Bell Labs in 1987. S-SEEDs are optical switches made of gallium arsenide built by molecular beam epitaxy, having a potential clock speed of one GHz and picojoule switching energies. The devices are 5,000 nm (nanometers) square and use two mirrors with controllable reflectivity to infrared light. The demonstration processor, which operates at only 1 MHz, contains 32 S-SEEDs and two laser diodes in each of four arrays connected by lenses and masks serving as logic gates.

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In 1993, University of Colorado researchers Vincent Heuring and Harry Jordan took the next step, unveiling the world's first general-purpose optical computer able to store and manipulate its own programming instructions internally. The prototype has the power of a small personal computer (3×10^6 bits/sec). But the inventors claim that using technologies already demonstrated in the laboratory they could build a palm-sized version 400 times smaller than the current prototype, and boost power into the 10^9 bit/sec range (Ref. 5).

Many strange ideas lurk on the horizon. Back in the early 1960s, Rolf Landauer of IBM suggested that the only logic operations that necessarily require the dissipation of energy are those which are thermodynamically "irreversible." That's how conventional computers work—logic circuits and other components are set up to run in one direction only. Landauer's observation has led to several proposals for quantum computers employing (1) reversible, dissipationless logic devices, (2) computations carried out using reversible logic alone, and (3) bits that are registered by true quantum-mechanical quanta such as spins.

Testing the first of these proposals in 1992, Xerox Corp. physicist Ralph Merkle and several collaborators sought to create more energy-efficient devices by rearranging a set of CMOS transistors into reversible switches (Ref. 3). They interspersed inductors among the switches in order to harvest electrical energy that would have been lost as heat, and fed it back into the power supply. The reversible circuits are 7.7 times more efficient than conventional ones, albeit much slower. "My rash prediction," says Merkle, "is that reversible logic will dominate in the 21st century."

The latest in reversible devices is Seth Lloyd's proposal for a "quantum supercomputer" (Ref. 6). The device, he explains, would be made of "arrays of weakly coupled quantum systems. Computation is effected by subjecting the array to a sequence of electromagnetic pulses that induce transitions between locally defined quantum states." For example, in one dimension the computer might consist of localized electronic states in a polymer; in two dimensions, quantum dots in a semiconductor, in three dimensions, nuclear spins in a crystal lattice. Lloyd achieves quantum-mechanically coherent computation by "preparing the array in a superposition of program states and then operating the array as a digital computer." The proposed device would not just be a universal digital computer, but also a general-purpose quantum-mechanical micromanipulator.

HUMANOID ROBOTS

As computers progress toward human intelligence, robots are taking more human form. "Cog," the latest project at Rodney Brooks's Artificial Intelligence Lab at MIT, may be the most ambitious humanoid robot ever attempted. Researchers hope the machine will eventually approach, and in some areas perhaps surpass, the mental and physical prowess of a six-month-old human infant (Ref. 7). Using mechanical eyes, ears, arms,

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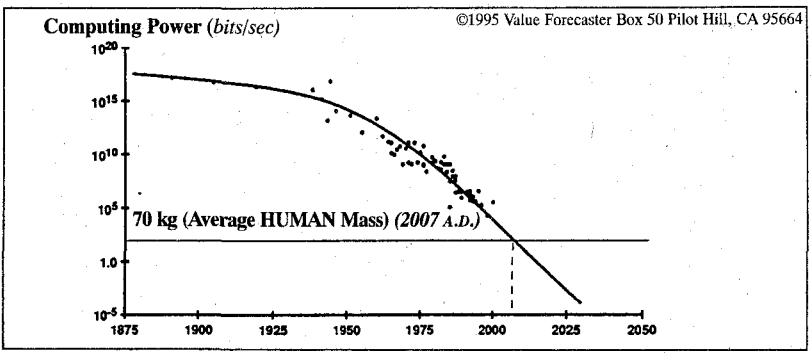

Figure 3. Mass of Human-Equvivalent (Teraflop) Computer Systems

fingers, and a computer brain inspired by human neuroanatomy, the robot will tackle questions such as how eye-hand coordination develops in the brain and how infants learn to interact with others. Complete realization of this goal could take a decade of work and millions of dollars.

Why is Cog so important? In the 1980s, Brooks, the controversial "Bad Boy of Robotics," built more than two dozen small, fast insect-like robots challenging the conventional wisdom that mobile, autonomous machines must extract a symbolic representation of the world from their sensory data before they can plan a course of action. Brooks's insect robots, in contrast, had a more direct coupling with the world, using simple sensors to continually modify and incite physical actions. For example, when a leg of one of his insects hit an obstacle, a contact sensor quickly invoked a reflex action like "lift leg" or "back up." Dozens of these stimulus-response reflexes were linked together in a rich web, giving Brooks's mini-robots surprisingly complex, robust—and quick—behavior.

During human evolution, Brooks says, the human brain must have developed thousands of solutions to everyday problems like seeing, hearing, and moving. Higher intelligence may simply be a matter of adapting these solutions in a novel way. "When you're building in the machinery that knows not to bump into things, how to get around them, et cetera, you're also building in a lot of the same machinery that does abstract reasoning," explains Lynn Stein, an MIT roboticist working with Brooks on the Cog program. Why the sudden leap from robot bugs to robot men? "I figure I have one more 10-year project left in me," laughs Brooks, who has labored in the AI vineyards for decades. "I'd hate to go out as 'he built the best artificial cat in the world.' "

When might a Human-Equivalent Computer fit in a machine the mass of a human body? The trendline on the chart in Figure 3, based on historical data from actual computers, implies a human-size teraflop system should arrive by the year 2007. By 2025, HECs

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should weigh as little as a credit card, like "SELMA" in the TV series *Time Trax*. By 2050, the curve reaches one microgram, a Human-Equivalent Computer the mass of a small paramecium. As you'll see below, these last two projections are unduly pessimistic.

NANOTECHNOLOGY

Molecular nanotechnology, a concept first articulated by Eric Drexler in the early 1980s, is the controlled manipulation of matter at the atomic and molecular levels to create new products with atom-by-atom precision. (A nanometer is about six atoms wide.) Drexler has since written three books on the subject (Refs. 8-10) with a fourth due out in 1996, and there are many other excellent summaries of technical progress in this rapidly growing area (Refs. 1,11-15). The field has its own journal, *Nanotechnology*, published quarterly since 1989. Interested readers can keep abreast of the latest developments, books, and conferences by becoming a member of Drexler's organization, the Foresight Institute (Box 61058, Palo Alto, CA 94306, 415-324-2490).

Where are we today? Engineers now manipulate matter at the atomic level, carving out 1-atom-deep "molecular corrals" and fabricating 1-10 nm scale "suspension bridges," "guitar strings," wires, magnets and bearings. (Complex biomolecules like insulin and hemoglobin are compact natural nanomachines about 2-3 nm in size.) The Atomic Force Microscope (AFM) and Scanning Tunneling Microscope (STM) permit the precise positioning of individual atoms. The newest machines cut the time required to etch 1-nm lines to seconds. In 1992, researchers at Harvard University used an AFM to perform nanomachining operations on a molybdenum trioxide crystal (Ref. 16). Using an applied load of 100 nanonewtons at the tip, they milled a triangular-shaped 50-nm part from the crystal, then slid the part 200 nm across the work surface. "Nanoparts" with features as narrow as 10 nm can be machined this way.

Smaller nanoparts can be constructed chemically. Recently, Professor T. Ross Kelly and his colleagues at Boston College created a "paddlewheel" molecule (a spinning propeller-shaped wheel) with a built-in brake. In solution, the wheel spins freely. When chemists add mercury ions, the brake trips, stopping the rotation. When they remove the mercury, the wheel resumes spinning (Ref. 17).

Nanoparts can also be hooked together chemically. Last year two British chemists created a self-assembling molecule consisting of five interlocked rings (five nanoparts) averaging 75 atoms per ring, arranged in the shape of the Olympic logo. This is the largest mechanically-interlocked molecule synthesized to date.

In a few years it will be possible to construct complex nanoparts consisting of a few thousand atoms, such as the planetary gear shown in Figure 4A, on a timescale of days. Once we get more proficient at building nanoparts, we can put a few hundred of them together to build the first nanotools consisting of millions of atoms, much like the hypothetical manipulator arm

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Figure 4A. Complex Nanoparts: A Planetary Gear

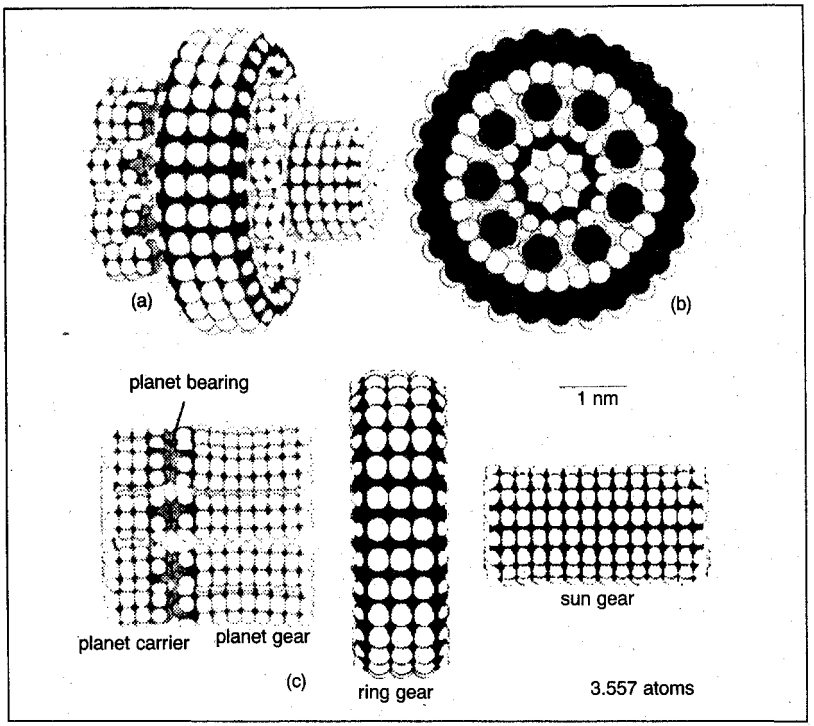
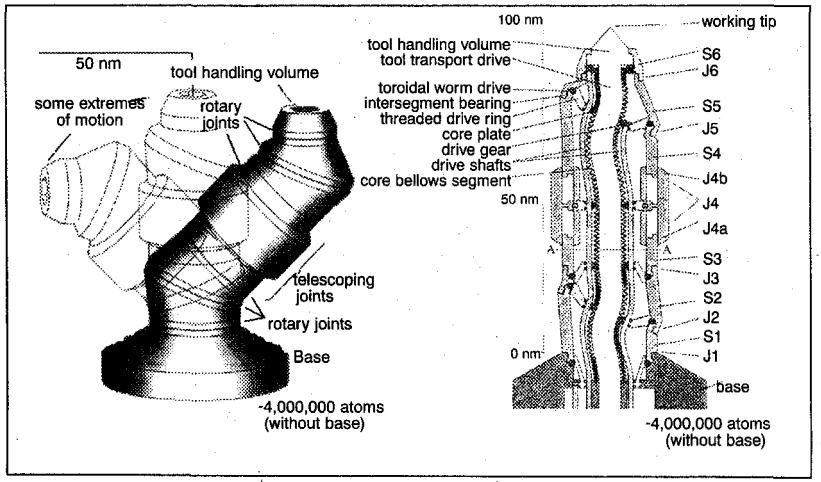


Figure 4B. Proposed Nanomanipulator Arm



Adapted from *Nanosystems: Molecular Machinery, Manufacturing, and Computation*, by K. Eric Drexler.

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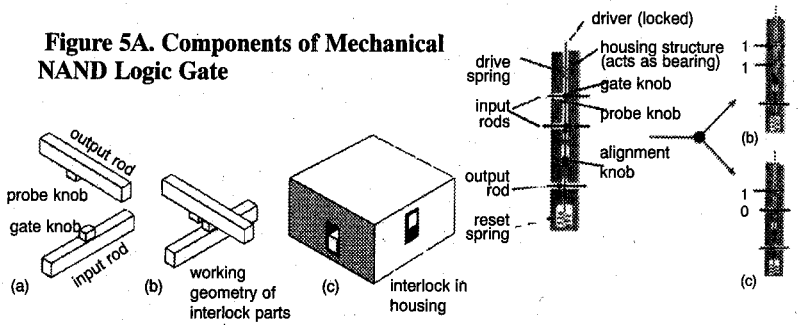
Figure 5A shows a nanomechanical implementation of a Boolean Not-AND, or NAND, operation, using clock-driven input and output logic rods which interact via knobs that prevent or enable motion, all encased in a housing. Figure 5B is an exploded diagram of the moving parts of a register capable of mechanical data storage, using rods 1 nanometer in width. Figure 5C illustrates a programmable logic array using logic rods (omitting several drive and spring systems for clarity), which, in combination with registers, can be used to build much of the control circuitry for a CPU (Central Processing Unit) in a clocked computer system.

Figure 5A. Components of Mechanical NAND Logic Gate



Adapted from *Nanosystems: Molecular Machinery, Manufacturing, and Computation,* by K. Eric Drexler.

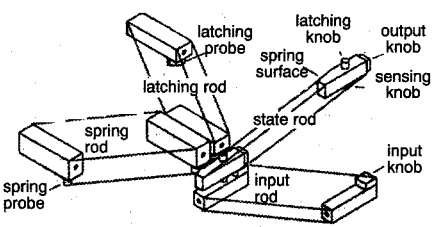


Figure 5B. Mechanical Data Register Using Logic Rods

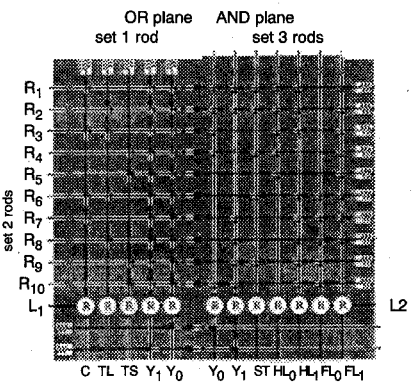


Figure 5C. Mechanical Programmable Logic Array

(good for nanoassembly work) shown in Figure 4B.

Nanoparts may also be assembled into nanomechanical logic devices. We can use l-nm sliding diamond rods to build gates (Figure 5A) and registers (Figure 5B) with 0.1-nanosecond switching speeds.* These devices could be combined to make programmable logic arrays (Figure 5C) with >1 GHz clock speeds. Drexler's

* Nanoelectronic systems should be much faster. The ultimate: A "nanooptical" computer limited by quantum theory to a clock speed of 10^{14} transitions/sec, a mid-infared frequency at 0.4 eV, about 10% of carbon-carbon bond energy. Attempting to clock faster than this would start tearing apart the switches. Note that a "nanooptical" computer is made of human-equivalent

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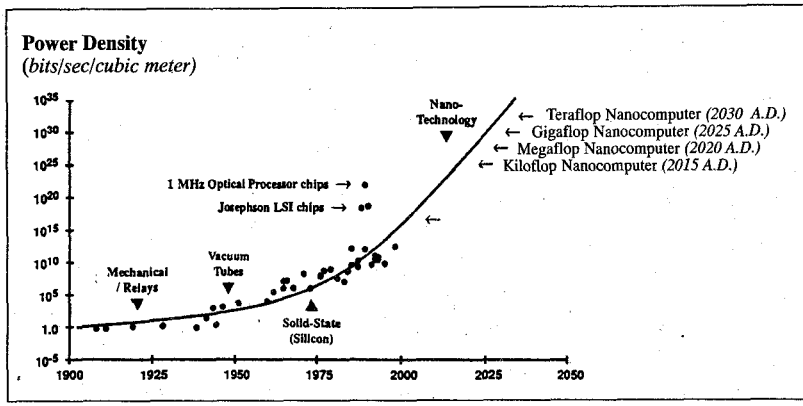

Figure 6. Rise of Data Processing Power Density in Computer Systems

benchmark nanocomputer with 100,000 logic rods, 10,000 registers, power supplies, etc. occupies a cube 400 nm on a side, weighs 10^{-7} micrograms, and computes at 1 billion ops/sec (0.001 teraflops) (Ref. 10).

How soon might we be able to build Drexler's mechanical nanocomputer? Figure 6 shows the evolution of data processing power per unit volume over the last 100 years. Drexler's design represents a computing power density of 5 x 10^{29} bits/sec/cubic meter, assuming 32-bit words. Figure 6 says this density should be reached by 2025, but we could see the first simple nanocomputer, performing just 1,000 ops/sec in a 100-nm volume, as early as 2015.

APPLICATIONS

I've collected the above projections into a single timeline (Figure 7). It looks like we'll be nearing the physical limits of nanotechnology by mid-21st century, a time when nanites and

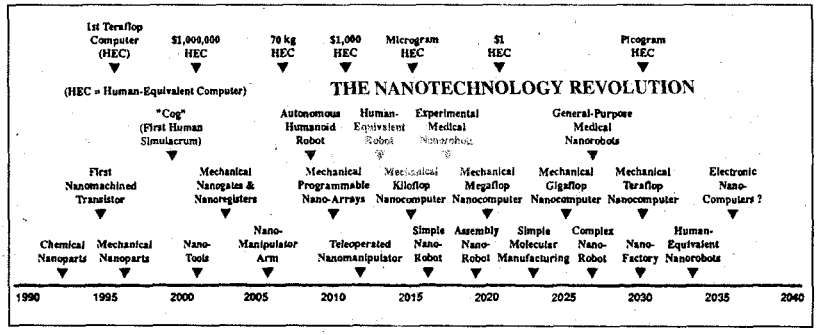

Figure 7. Probable Timeline of Nanotechnology Development: 1990-2040

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Figure 8. Specifications for Drexler's Nanorobotic and Nanocomputer Reference Systems

Specification	10-Micron Nanite	1-Micron Nanite	0.1-Micron Nanite	Exemplar Nano-Manufacturing System (or Generic)
System Size	10^{-5} meter	10^{-6} meter	10^{-7} meter	0.3 meter
Number of Atoms	10^{14} atoms	10^{11} atoms	10^{8} atoms	10^{25} atoms
System Mass	2×10^{-12} kg	2×10^{-15} kg	2×10^{-18} kg	1 kg
Parts Assembly Speed	10^{4} ops/sec	10^{4} ops/sec	10^{6} ops/sec	5,020,555 ops/sec
CPU Data Proc. speed	2×10^{13} ops/sec	2×10^{10} ops/sec	2×10^{7} ops/sec	3×10^{13} ops/sec
Data Storage, RAM	10^{10} bits	10^{7} bits	10^{4} bits	10^{20} bits
Data Storage, Tape	10^{13} bits	10^{10} bits	10^{7} bits	10^{23} bits
Power, Physical Tasks	10^{-7} watts	10^{-10} watts	10^{-13} watts	4×10^{4} W/kgNanites
Power, Computational	10^{-3} watts	10^{-6} watts	10^{-9} watts	5×10^{8} W/kgNanites
Max. Physical Velocity	-----	-----	-----	0.001-10 meter/sec
Mfg. System Output	-----	-----	-----	9 gm product/sec per kgNanites

Living Cell Sizes:	
Smallest Free-living	0.2 micron
Average Bacterium	2.0 microns
Mammalian Tissue	20 microns
Amoeba/Protozoans	200 microns

Working Strengths of Materials:	
Diamondoid	100×10^{9} J/m^3
Interlocked Van der Waals	10×10^{9} J/m^3
Ionic/Steel/Aluminum	3×10^{9} J/m^3
Simple Van der Waals	1×10^{9} J/m^3

Human-Equivalent Computers will be as ubiquitous as electricity, indoor plumbing, ball-point pens and automobiles are today.

Lots of interesting applications have already been mentioned in print. A few notables: Video paint; self-repairing mountain-climbing rope; shape-changing cars, houses, furniture and clothing; self-cleaning carpets and windows; conscious control of pregnancy, sleep, and physical appearance (metamorphic cosmetics, programmable tattoos); complete automation of personal hygiene including hair, skin, teeth, and bowels (use your imagination); nanofood (synthohol, programmable flavors); nanodrugs (Library pills, externally switchable analgesics and aphrodisiacs, rejuvenant "Venus" pills); self-assembling critical masses of radionuclide-rich nanites (atomic stealth bombs); and the ability to read, copy, rewrite, add, erase, transfer, or exchange thoughts and memories to the brain, with or without cooperation (lie detection, mental rehabilitation).

By the mid-21st century, nanotechnology will make possible many science fiction inventions once relegated to the distant future. Very little lies beyond our grasp. Figure 8 summarizes the characteristics of representative nanomachine systems as they are likely to exist by 2040, using parameters derived from Drexler's textbook (Ref. 10). The following extrapolations strictly conform to all gross engineering specifications in the table. As is common in exploratory engineering exercises, we attempt to make the case that certain future systems are physically possible, not to actually design those systems today.

The results are—to me—simply astounding.

Tractor Beams. Consider a tractor

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beam in space, designed to hold, say, a 1000-ton object motionless against a 1-*g* shearing force, 1 km from your ship. Rather than some unspecified and mysterious beam, we use a physical cable with a 1-centimeter diamond core coated with a 10-micron layer of 0.1–1.0 micron nanites. The diamond core is in short segments so the hawser stays flexible during storage and deployment.

A 1-km length of coiled cable weighing 300 kg is paid out from a beachball-sized pod fired at 1 km/sec towards the target. Using windlass brakes the pod decelerates and impacts the target at low speed. Pod nanites secure it to the object with diamond microanchors and molecular welding. Assembler nanites in the coating weld the diamond-core finger-jointed segments into a seamless, rigid column of flawless crystal and fibers that can be used to push, pull, or station-keep, while other nanites act to dampen unwanted oscillations. (Acoustic signals travel 17 kilometers/sec in diamond.) The entire (reversible) process takes one to two seconds. You need at least three kiloton-test diamond nanohawsers for full positional control. Each line draws up to 25 kilowatts of power.

Force Fields. To establish a restraining field across a 3 x 3 meter doorway, you release six ounces of 0.1–1.0 micron nanites along a hairline guide strip on the floor spanning the aperture. The little buggers climb all over each other, joining hands and raising themselves evenly in a 10-micron-thick multi-layered sheet extending from floor to ceiling, wall to wall, following the guide strip, in about two seconds.

This barrier won't halt high-speed bullets—you'd need a centimeter-thick nanowall for that. But the surface is strong enough to stop a human running at world-record sprint speed. (It can also hold back STP air against vacuum in a six-meter pressure vessel—makes a dandy airlock or ad hoc spacecraft observation bubble.) Field nanites detect stress and adjust field thickness to redistribute sudden physical or thermal loads. A reflective surface scatters laser beams harmlessly. A sharp object like a knife penetrates at the point, but nanites grab the blade along the broad flat edge and prevent further entry, then expel the weapon. The field, roughly 100 nanorobots deep, consumes one kilowatt of power to hold structural integrity, can undulate and push back when challenged, and would shimmer, crackle and hum (as in *Star Trek*) if electrified.

SuperHero Suit. Imagine wearing a body suit made of intelligent armor fabric half a millimeter thick—probably thinner than the shirt you're wearing now. Armor fabric is a sheet of 400-micron-thick flawless diamond, broken into small plates to allow flexing and embedded in a diamond mesh fabric. Plates are coated top and bottom with a 100-micron layer of 1-micron active nanites providing structural support, repair, and powerful artificial muscular action.

The suit stops high-velocity (700

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m/sec) slugs and 1-ounce shrapnel, and reacts fast enough to stiffen locally under deformation. If anyone throws a punch, it feels like hitting steel to them, but hardly a tap to you. The fabric works as a powerful exoskeleton, allowing the wearer to lift (and resist crushing by) up to 5–10 ton loads. (If you give the nanites a couple of seconds to weld the diamond plates into seamless crystal, the garment goes selectively rigid and supports 1,000-ton static loads.) You should also be able to make 15-foot vertical leaps, jog comfortably at 25 mph and sprint to 60 mph. Of course, the suit does virtually all the work during these feats, piloted, in effect, by its human "passenger." (Imagine a motorized pogo stick.) The outfit weighs 4 kg, consumes up to 40 kilowatts of power drawn from 4-kg hour-power packs, and stows itself to the size of a grapefruit.

Phasers. Phaser weapons can be nanotechnological devices. Here's how they might work. Set to stun, the firearm sprays a narrow low-energy beam of nanites capable of inducing coma in the target in under one second by entering the body and overloading skin sensor or optic nerve inputs, gobbling neurotransmitters, or scrambling brainstem signals. Set to freeze, a 1-gram beam of 1-micron nanites rapidly encases the target (reversibly) in a skin-tight, steel-rigid webbing, making a living statue much like the "stun gun" in the old Flash Gordon series.

With phaser set to kill, there are countless ways nanites can cause near-instant death, some painless, others not. On *Star Trek,* the kill setting includes full disintegration. To kill with disintegration, we spray the target with 0.1-micron nanochoppers studded with arrays of lightweight manipulator arms that can reach out and rapidly yank molecules apart. Upon firing the weapon, the physical boundaries of the intended target are marked by fast-moving surveyor nanites. A millisecond later, the nanochoppers arrive in large numbers and disassemble all matter within the mapped target volume, then self-destruct. A 5-gram charge of nanochoppers atomizes a 70 kg human body in one second, relying in part on energy released by catalyzing the combustion (in air) of all organics into clouds of water vapor, carbon and nitrogen oxides.

Replicators. Another *Star Trek* staple, the food replicator, will put most farmers out of business by the mid-21st century. Nano-manufactured food will be structurally and nutritionally perfect—no contaminants and precisely specified levels of vitamins, minerals, fats, bones, fibers, sugars, flavors, colors, textures and intoxicants.

As seen on *Star Trek*, the replicator operates by dropping a cylindrical nanite force field onto the worktable, then sterilizing and evacuating the interior. The force field provides workpiece scaffolding and cooling. The replicator fills the workspace with the most efficient mix of manufacturing nanomachinery of various sizes. These nanites draw from a raw materials feedstock containing a broad se-

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lection of small organic molecules previously extracted from fecal sludge tanks, recycling bins and atmospheric scrubbers.

Let's say you've ordered a juicy 8-oz steak, medium rare. Following Drexler's "exemplar manufacturing system" (Ref. 10), a 6-kg population of 10^{17} nanites fills a volume of 3,000 cubic centimeters and assembles the steak in four seconds. The work volume is flushed clear, the atmosphere replaced. The force field lifts, and there's your sizzling steak on a plate, ready to eat. Interestingly, replicated food is far cheaper than farm-grown fare. Your 8-oz steak costs only 1 megajoule of energy to assemble (3 cents' worth, at today's prices), versus 20 megajoules using cattle, feedlots, slaughterhouses, packers, truckers, and supermarkets. Even the simplest grain foods cost half as much energy to replicate as to produce agriculturally. By 2100 A.D., farming will be a historical curiosity.

Note that replicators are not elemental transmutators. They can't turn lead into gold. All they do is rearrange atoms, already abundantly present, into more useful configurations.

Immortality. Your medical exam begins with a comprehensive Cellular Audit. The doctor sprays you with a fine mist containing a trillion 1-micron diagnostic nanites (two grams) including thousands of functional specialties. Each of these highly-mobile sensor-studded nanosubmarines (Ref. 18) visits and observes one cell in your body every second, gathering enough data to fill a hundred-page report at each stop. In 10 seconds, nanites visit every cell in your body, report the results to your doctor, and clear out. Anything suspicious is investigated further and, if necessary, fixed by a second dose of cellular repair machines.

Nanites can provide a programmable immune system to rapidly destroy any bacterial, viral, or nanomechanical invader listed in the global pathogen database. Major traumas are easy to repair. Embedded bullets or shrapnel are exuded, and lacerated tissues repaired, almost instantly. For example, a 1-inch deep, 1-inch long cut is sterilized and resealed in 1 second using 100 cubic millimeters of active 1-micron nanosuture robots each able to reconnect ten thousand tissue molecules per second.

Senescent cells are reactivated, damaged cells repaired, degenerate brain cells rebuilt, cancerous cells replaced. Nanodocs should be able to eradicate virtually every cause of aging and death except murder, suicide, legal executions, and accidents involving permanent personality loss. The 1992 US death rate was 853.3 per 100,000 population, all causes. Life expectancy was 75.5 years at birth. Eliminating all but the above four causes leaves just 55.9 deaths per 100,000, an implied life expectancy of 1,150 years. That's effective immortality, by today's standards.

Other biological implications of nanotechnology are equally profound. We'll soon have to deal with nanoeugenics, bionic pathogens, pa-

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leocloning and thanatocloning, man-machine cellular symbiosis, brain transplants, interspecies hybridization, de novo genetic design, biostasis (suspended animation) and ecostasis, nanoterraforming, and—my personal favorite—self-replicating nanorobots.

Invisibility. Nanotechnology makes possible the Invisible Man. Imagine a skin-tight suit coated with a layer of digital fisheye optical transceivers. Photons detected on one side of the suit are measured for frequency and incidence geometry. This data is relayed to appropriate transceivers on the opposite side of the suit, where photons of like frequency are emitted in such a direction that their line of flight appears uninterrupted.

We have no idea how to engineer this system today, but we *do* know that nanocomputers can handle the required dataflow. Here's the worst-case analysis. Human eye resolution is 1 arcmin. At closest focus (10 cm), that's 30 microns or 1 billion pixels per square meter. Assign one fisheye transceiver, and one l-micron nanocomputer, per pixel. Each of the 1 billion fisheyes must present one viewplane per square arcmin, a total of 100 million viewplanes. Using 20-bit words to code 1 million distinct color values and scanning at 100 frames/second, we process 2×10^{20} bits/sec per square meter of suit surface. This computational load is easily handled by our 2 milligrams of nanites consuming 1 kW of power, backed by a densely webbed optical fiber databus.

We can use the same technology to camouflage or "cloak" ground vehicles, buildings, airplanes, and spacecraft.

Transporters. General-purpose matter transmission appears possible using nanosystems, but really pushes the edge of the envelope. The crude method I'll describe has at least three serious drawbacks. Transmission must be: (1) line of sight (no beaming through walls), (2) station-to-station (must have transmitter and receiver), and (3) in vacuo (no beaming through atmospheres).

To transmit, a 100-kg payload is placed on a l-meter diameter floor pad. The transmitter system throws a restraining net over the payload to immobilize it for scanning, then drops a cylindrical force field the diameter of the pad and evacuates the cylinder. Eleven tons of nanites of various sizes fill the cylinder and perform a hierarchical decomposition of the payload using a fixed scan geometry, reading each of 10^{28} atoms as an 8-bit word thus generating 10^{29} bits of structured compositional data. Using a 5 gigawatt nanolaser array and one blue photon per bit, we transmit the entire description in 10 seconds—consuming 50 gigajoules of energy (about $1,500 worth at today's power costs)—to a distant receiver, say, 100 kilometers away, where the compositional data is decoded, driving payload reconstruction.

It ought to work fine with inanimate objects, but would live cargo survive? I'm with Dr. McCoy—you couldn't pay me to step into the thing!

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The Holodeck. Nanite populations can configure themselves into complex surfaces of any shape, size, or texture. You could carry a kilogram of them—enough to construct 50 square meters of programmable 10-micron surface—in your handheld MakePad, a combination control and storage unit hung at the belt. These nanites could be programmed to make force fields in the shapes of chairs, tables, beds, even a smart trampoline. (Wouldn't that be fun!)

For the holodeck, more elaborate nanosurfaces are configured into shapes resembling people, animals, plants, buildings or machines, using mostly ballast mass and structured filler material to build to minimum human eye resolution. Hefty onboard computer power plus artificial internal tendons, bellows, heaters and other specialized nano-organs give these assemblages the ability to move around, talk, eat, and otherwise perfectly simulate the real thing.

NanoGhosts. An aerogel of nanites would make an excellent poltergeist! A structured cloud of 1-micron nanites weighing 50 milligrams occupying the volume of a human body could retain its physical integrity in a 60 mph wind, lift and hurl 1-kg objects, emulate an angry personality, suck energy out of electrical outlets, and reshape itself into jets and airfoils to flap around rooms riding the 0.1–0.5 mph household currents caused by fans, air conditioners and human movement.

Precognition and Psychohistory. The advent of nanocomputers will make it possible to create detailed simulations of human sociocultural process. Elaborate psychosocial models of individual people, their communities and physical environments might lead to foreknowledge of general outcomes in personal lives about as reliable as one to two week weather forecasts are today.

Scientists in a single cliology laboratory could assemble 15 billion Human-Equivalent Computers (one for each person on Earth in the year 2040), a sugarcube-size metacomputer weighing two grams. Researchers could then run historical simulations of human civilization a million times faster than real time, testing theories and developing reliable forecasts. Human cultural evolution will become at least as predictable as the behavior of social insects is today, although mechanocultural evolution may remain intractable.

Psionics, Magic, and Miracles. By positioning one telemetered nanite in each of the brain's 10 billion cortical neurons (total of 20 milligrams, 1 watt of waste heat), it becomes possible to directly read and transmit real-time brain states from one mind to another—true telepathy. Once a mental link exists, you could use it to command the activity of nanites around you to move objects (telekinesis), to harm others (hexing), burn objects (pyrokinesis), to mind-read other people (empathy) or animals (telezoopathy), to sense remotely (dowsing), to teleoperate or "Waldo" another brain (zombification), or to mind-clone (possession).

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Nanotechnology will also make it easy to wow the primitives (anyone lacking post-20th-century knowledge) with magic tricks or "miracles" such as levitation, patterned bleeding (stigmata), turning staffs into serpents and (muddy river) water into wine, healing the sick, parting seas, and so forth.

NANOCREATURES

A two-square-meter (human-size) nanosurface comprised of 4-micron nanocomputers, 32 microns thick, represents a population of a trillion individual nanites each possessing teraflop (human-equivalent) intelligence but collectively weighing only one pound. By the mid-21st century, we may see a startling variety of strangely-shaped organisms made up of trillions or quadrillions of independent HEC nanocells, all voluntarily associated on a temporary basis to achieve some (to us) mysterious objective. Even the smallest of these macroscopic creatures will be protean in shape and mass, something like the liquid robot in *Terminator 2,* but hypersentient. By comparison, modern conceptions of advanced robots like *Star Trek*'s Mr. Data appear laughingly primitive.

Consider: Each nanoorganismic collective is a microscopic nation of intelligence more akin to human civilization than to individual people. A nanocreature could bud off tiny chunks of itself, each capable of independent motion with superhuman mentality, to serve as information seekers, materials gatherers, weapons, or other independent agents. Or, like the cartoonish "Power Rangers," nanoorganisms could temporarily merge to form larger entities for special purposes. Nanocreatures could manufacture virtually anything and reproduce at will, qualifying by any reasonable measure as a higher form of life than our own.

How would they regard us? Mathematician I.J. Good once remarked that "if we build an ultraintelligent machine, we will be playing with fire. But we have played with fire before, and it has helped to keep the other animals at bay." Hearing this, Arthur C. Clarke retorted: "When artificial intelligence does arrive, *we* shall be the other animals; and look at what has happened to *them*. It will be poetic justice."

So get ready. It's going to be an interesting century.

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About the Author

Robert A. Freitas, Jr. has written or edited nearly 100 popular articles, technical papers, and books on diverse scientific and legal topics, computer science, robotics and automation, astronomy and xenology. His first published piece—on the legal rights of extraterrestrials—appeared in the April 1977 *Analog*. After obtaining degrees in physics, psychology, and law, he produced the first how-to book on space program political advocacy called *Lobbying for Space,* conducted the first optical SETI search for Earth-orbiting alien artifacts and the first radio SETI search at the tritium line, and in 1980 was a principal contributor to NASA's first serious engineering study of self-replicating robot systems in space. Since 1988 he has edited and published *Value Forecaster,* a monthly financial newsletter, and has developed a 1000-equation nonlinear econometric computer model to forecast the economy and investments 60 months into the future. Freitas lives in California with his wife of 21 years in a home they spent half a decade designing and constructing. ■

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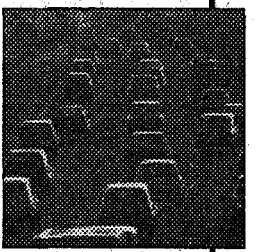
BAN DIHYDROGEN MONOXIDE!

THE INVISIBLE KILLER



Dihydrogen monoxide is colorless, odorless, and tasteless, and kills uncounted thousands of people every year. Most of these deaths are caused by accidental inhalation of DHMO, but the dangers of dihydrogen monoxide do not end there. Prolonged exposure to its solid form causes severe sweating and tissue damage. Symptoms of DHMO ingestion can include excessive sweating and urination, and possibly a bloated feeling, nausea, vomiting and body electrolyte imbalance. For those who have become dependent, DHMO withdrawal means certain death.

Dihydrogen monoxide:

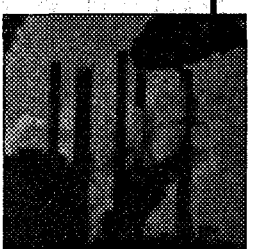
* is the major component of acid rain.
* contributes to the "greenhouse effect."
* may cause severe burns.
* contributes to the erosion of our natural landscape.
* accelerates corrosion and rusting of many metals.
* may cause electrical failures and decreased effectiveness of automobile brakes.
* has been found in excised tumors of terminal cancer patients.

CONTAMINATION IS REACHING EPIDEMIC PROPORTIONS

Quantities of dihydrogen monoxide have been found in almost every stream, lake, and reservior in America today. But the pollution is global, and the contaminant has even been found in Antarctic ice. In the midwest alone DHMO has caused millions of dollars in property damage.

Despite the danger, dihydrogen monoxide is often used:

* as an industrial solvent and coolant.
* in nuclear power plants.
* in the production of Styrofoam.
* as a fire retardant.
* in many forms of cruel animal research.
* in the distribution of pesticides. Even after washing, produce remains contaminated by this chemical.
* as an additive in certain "junk-foods" and other food products.



Companies dump waste DHMO into rivers and the ocean, and nothing can be done to stop them because this practice is still legal. The impact on wildlife is extreme, and we cannot afford to ignore it any longer!

THE HORROR MUST BE STOPPED

The American government has refused to ban the production, distribution, or use of this damaging chemical due to its "importance to the economic health of this nation." In fact, the navy and other military organizations are conducting experiments with DHMO, and designing multi-billion dollar devices to control and utilize it during warfare situations. Hundreds of military research facilities receive tons of it through a highly sophisticated underground distribution network. Many store large quantities for later use.

IT'S NOT TOO LATE

Act NOW to prevent further contamination. Find out more about this dangerous chemical. What you don't know CAN hurt you and others throughout the world. Send e-mail to no_dhmo@circus.com, or a SASE to:

Coalition to Ban DHMO
211 Pearl St.
Santa Cruz CA 95060

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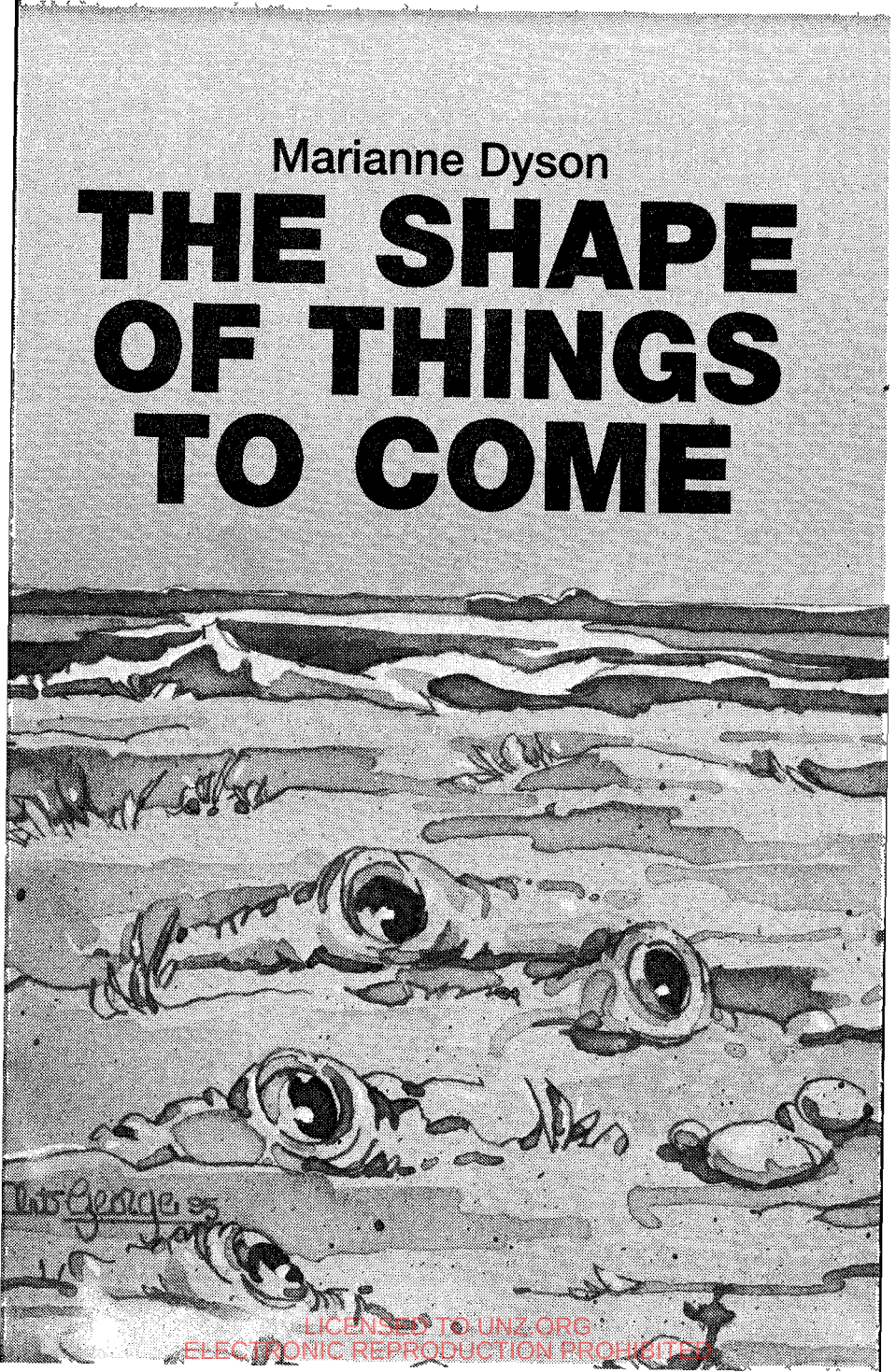
Marianne Dyson

THE SHAPE OF THINGS TO COME



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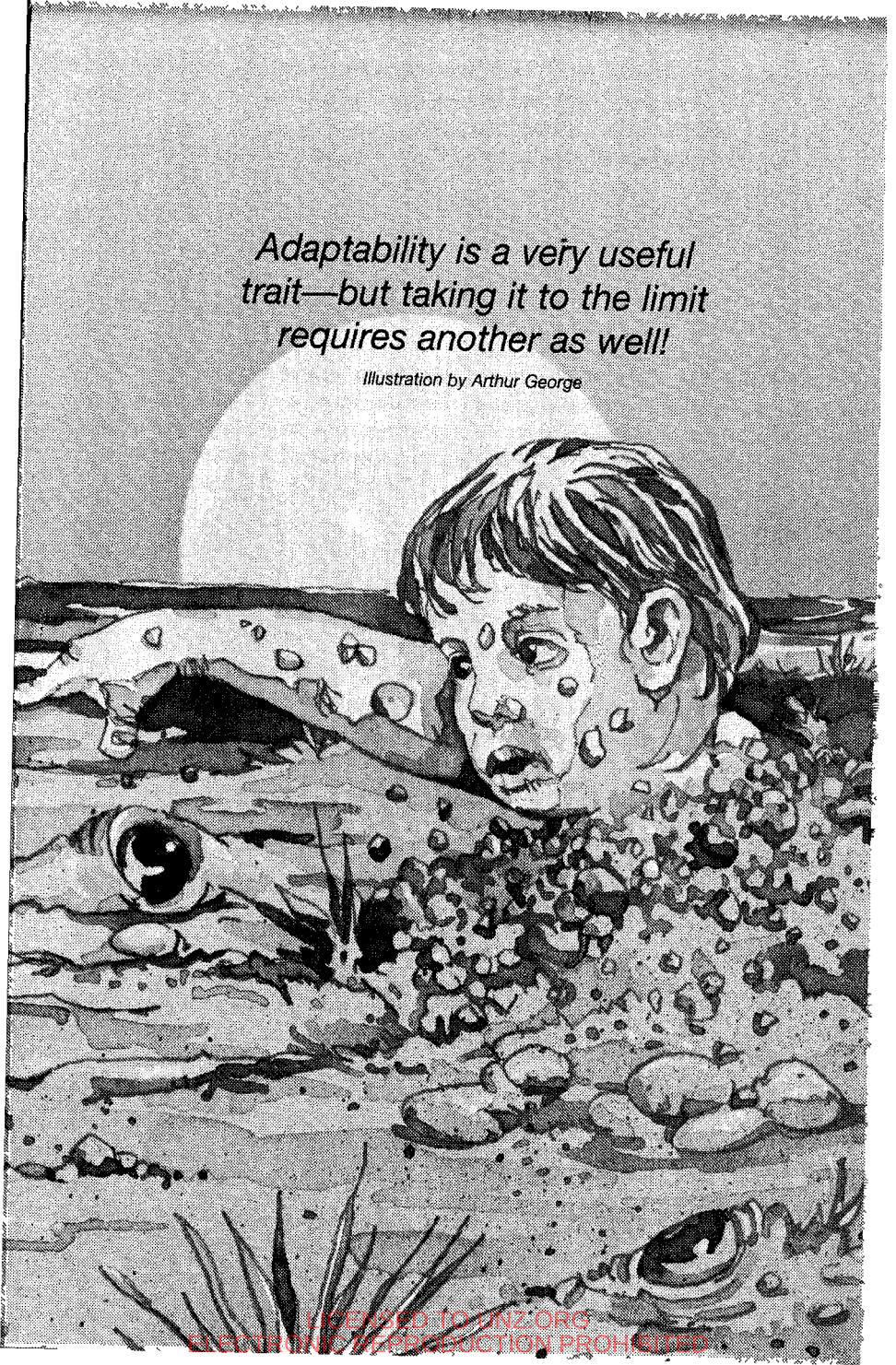
Adaptability is a very useful trait—but taking it to the limit requires another as well!

Illustration by Arthur George



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It was hot on the beach, so Suetork spread herself nearly flat, her transparent sphere becoming a ring of what appeared to be damp sand. She scattered her black eyes around like pebbles, on the watch for predators who might recognize her kind despite the careful camouflage.

"Alert! Movement—possible predators," Enupten, the leader, relayed. She was sunbathing farthest from the blue deep, but not far enough for Suetork. Just because she managed to evade the keen eyes of an elaw by superb blending of shadow shades, Enupten thought she was better than the rest of them.

Suetork rearranged her eyes into the warning cluster. One of her sisters, in the mundane shape and color of sea slime, got the message and rolled her "tarball" eyes into the same configuration. The message was thus transmitted all down the beach.

As Suetork readjusted her eyes, her sensor hairs detected sound waves from the direction of the predators. She formed a shell shape to better receive the message, but it was not an elaw code she recognized. Firming her surface by squeezing out bubbles, she watched the predators move closer, hoping her new form would protect her. She took a great deal of satisfaction in trying out new shapes, but if it were too different, the elaw might be suspicious and attack. She noticed Enupten was quick to copy her, though the imitation was a bit sloppy around the edges.

The strange code did not prepare her for the even stranger shape of the two predators. What kind of weather would cause a being to bunch itself vertically and move by alternating two long, skinny appendages? A shape like that could be seen against any background! Had the elaw gone mad?

The two tall beings carried a long white thing and a large black rock between them. She watched as they dropped these things on the sand, wondering if they were food. If so, they were unlike any base shape she had ever seen a creature take upon death. It took a tremendous amount of energy to maintain sharp features, and most things were dull, not shiny, once the life no longer pulsed within. Yet the rock-thing maintained many sharp corners.

While one being did something to the rock, the other removed a trap sack from its back and dumped a small version of itself onto the sand. Suetork quivered in relief. These beings were not an immediate threat—they had brought their food. Perhaps they needed that weird shape to catch the food and had not changed yet? Suetork knew small beings like her kind had an advantage in the speed with which they could change shape. The massive predators, like elaw, sometimes took hours to change.

Yes, that must be it. These were some new extra large size elaw that had just returned from hunting in the odd lands beyond the dunes. Suetork imagined the challenge and excitement of surviving in a land with so many strange shapes! She doubted Enupten had enough creativity to last a day in such a place.

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The beings were either stupid or not hungry, because they let their food crawl away. The food must have been injured during capture because it did not change shape, even when it reached the wet blue deep. Suetork began to suspect the food was not food after all, but a young one of the larger beings. It needed its leaders to change shape first so it could copy them.

She communicated this idea to Enupten, but she rudely displayed her opinion by allowing a gas bubble to pop in Suetork's direction. The young ones in the group happily imitated this gesture. Though Enupten chided them, it was obvious to Suetork the leader enjoyed teaching the young these bad manners.

But when a wave broke over the "food" and it didn't change shape, even Enupten had to admit Suetork was most likely right. It was stubbornly maintaining its leaders' current shape to show how strong it was, even though it nearly drowned for its efforts. Suetork felt sorry for it.

One of the adults moved the little one away from the waves to a spot near Enupten. What they needed to do was show the offspring a new shape, but Suetork guessed they were too stupid to realize this. She could not fathom why they would take that awkward vertical shape in the first place. Every living thing must change to suit the environment or die. Surely they had been trying for something else and failed.

The sand and sun were hot, very hot, and the stupid beings did not spread out or turn white to reflect the heat. Even the brainless dipputs could do that! The poor small one sat there drying out and making bubbling-blue noises which the leaders ignored.

Suetork's many delicate surface sensors, straining for sounds of approaching elaw, were suddenly overwhelmed into flatness against her skin by a thundering roar generated, at least it seemed, from the dead rock thing.

Luckily, the roar was of short duration, subsiding into a low, but rather familiar sound. If she didn't know better, she would swear the tall beings had somehow gotten the dead rock to suck the wet blue like a sand thog, using the white thing for a hollow reed! Why the tall ones would do this made no sense at all to Suetork. Dead things do not need to drink! Her opinion of the beings' intelligence dropped to dumber than dipputs. Maybe intelligence decreased with addition of mass?

As the day progressed, it got hotter and hotter, but the beings still did not alter their shape. The wind changed from still to blow-away force and back to still and the beings looked the same. Suetork got shinier in the heat and opened holes for the wind to pass through. Enupten allowed her surface to bubble, producing rainbows to impress the young ones. Suetork hated showoffs. A good leader saved her energy for danger. Though these weird beings appeared not to be a threat, there could be an elaw hidden in the dunes this very moment.

Enupten continued her display, and understandably, built up quite an appetite. She boldly announced she intended to trap and eat the small be-

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ing. Suetork objected, shaking her eyes at Enupten. Taking advantage of a helplessly stupid creature was not appropriate behavior for a leader. She stopped just short of accusing Enupten of being too lazy to find more challenging prey. She would not risk the safety of the entire group by arousing her to fight where there might be elaw.

Suetork monitored as Enupten slid across the sands and wiggled underneath the small one. The poor thing must have sensed the danger it was in because it smeared sand over its pink outer skin. Such a pitiful attempt to blend in with its surroundings! Enupten easily captured the being in a clear bubble.

The being thrashed about inside the skin of the trap. Its shape stayed the same, and it turned, not yellow like the sand or clear like the trap, but red! Suetork's anger with Enupten grew as she refused to quickly end the poor thing's miserable existence. A proper leader would not play with her food!

While the large beings were out of sight behind their rock-thing, their trapped young one changed color from red to blue. Suetork hoped that meant it would turn to liquid and escape, depriving Enupten of an easy meal. But it stubbornly maintained its shape. Suetork admitted to a certain curiosity as to what its base shape might be. If it were some kind of mutant elaw, it would turn to a gray log as it died.

Before the thing reverted, though, Enupten formed little teeth to bite it. "Mmm, salty!" she signaled. Suetork quivered in angry disgust. She could not remain in a group where a leader spread so low as to eat live prey! Enupten must be scattered immediately. Cautiously, so as not to attract attention from hidden elaw, Suetork slid next to Enupten.

"I challenge you as leader," she signaled with her eyes.

Enupten could not fight her and eat, so she let the trap bubble collapse into vinelike ropes to hold the creature. But before they engaged, the wounded thing responded by emitting a high frequency wail, warning its leaders. Suetork noted the little thing had enough sense to use a warning code likely to be captured above the loud sucking of the rock-thing. Being able to warn the group to flee would be especially important for creatures that couldn't change shape quickly.

Seeing one of its kind trapped, logically, Suetork expected them to cut their losses and flee. But the second tallest being not only rushed toward the small one, it threw a rock at Enupten.

This action confused Enupten, but Suetork suddenly understood. These creatures had found and killed some other whose base shape was rock-like. If the small one added mass suddenly by eating this rock, it could break away. Perhaps these beings were not as dumb as they looked.

As she'd done to evade elaw, Enupten shifted air from her holding sack to the impact point. The rock bounced off harmlessly.

Then the tallest one took a straight section of the white thing, which Sue-

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tork had now decided must be a form of tall dried grass, and swung it at Enupten's vines with a force that shook the sand! Suetork was both shocked and amazed. The longer an appendage, the weaker it should be. But the blows were anything but weak. Enupten tried the bubble routine, but she had used up too much energy with her showing off and playing around to move quickly enough or change to liquid form and escape. The tallest one pounded Enupten into pieces.

Each piece of Enupten which held an eye had the potential to grow into a new creature. The weather, the elaw, and other predators would make sure only the best survived. Suetork hoped a smarter Enupten would evolve in a few seasons.

As soon as Enupten was scattered, the one who threw the rock snatched the small one to its front. Suetork noted the small one was leaking where it had been bitten and also from its two main eyes. The large one pressed it to its mouth. Suetork rolled her eyes to one side, knowing what this must mean. The small one was probably leaking too much to save, and was too young to scatter. The leader, with more manners than Enupten had shown, meant to put a quick end to the little one's suffering by eating it. Many species did that, but Suetork had no desire to watch.

She turned just in time to see the tallest one swinging at her with its deadly white thing. Already it had scattered several of the young ones, all of whom had copied Enupten's . . . Suetork's shape! She should have realized this large a creature would require many pieces for food. As the blow struck and the pain shot through her, Suetork knew she would soon be scattered. She must retain this unlucky form to distract the being, giving the others time to change and escape. She signaled to one of her sisters to have the group use the blue wave shape with eyes of shells in the surf.

As the group changed, edges curling into white foam tinged with pink, Suetork braced for the next blow. To her surprise, it merely scratched. The being apparently had run out of energy. It threw the white reed-thing down and rushed away, clumsily throwing sand everywhere.

Suetork blocked her pain, and wished she could join the others in the soothing blue. But, all around her were the eye-pieces of Enupten. As much as she had disliked the former leader, she would not slide over her eye-pieces and crush them. Besides, her wound would bleed upon the sand or into the blue and bring the elaw or sand thogs upon them all. For the safety of the group, she would have to stay apart from them until her leaking stopped.

Some of her sisters floated as oil stains on the blue, offering what comfort they could from a distance. They would wait to see her fate, recording her interaction with the tall ones as a lesson to be shared with others of their kind. They honored her bravery with their own, but they were in danger as long as they waited so close to her seeping fluids and Enupten's. Elaw were pretty stupid, but they

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would scent her soon. As if in response to her thought, one of her sisters signaled from the wet blue, "Alert! Elaw approaching!"

Suetork moved her eyes back toward the dunes. There they were, two elaw disguised as large rolling bushes with black thorn eyes, coming her way. Only the sight of the tall beings made them hesitate. Elaw rarely risked attack by more massive creatures than themselves. For example, they would never attack Suetork's kind during the annual mating when the group merged into one giant creature.

Eventually though, if the tall ones continued to ignore the fresh food on the beach, the elaw would conclude, as she had earlier, that the tall ones were not hungry, and therefore not a threat. Then the elaw would come for her.

As one of the tall ones turned its eyes away from her direction, perhaps sensing the elaw, she noticed the small one clung to its back! So, it had not been eaten after all. It had also reverted to its previous pink color.

While Suetork waited, wondering which species would claim her first, she distracted herself by considering how the tall shape might have survival value. Being large and slow, the beings must have been attacked often. The ability to lift young ones so they didn't leak on the sand and attract additional predators would be useful. It was similar to her old leader's trick of making a leak into a pool. It worked great for small leaks caused by thorn scrapes or falls. These quickly dried in the sun. Unfortunately for her, Enupten's scattering released fluids and food that would continue to attract scavengers for days.

Unless. . . . What an idea! If the tall ones were as dumb as she imagined, it should not be too difficult to fool them into thinking she was one of their young ones! They would pick her up and carry her to safety. Later, she would change into something else, and they'd never know what happened. It just might work!

All her life Suetork had changed to suit her environment. Now was her chance to try out a really different shape.

Quickly, she studied the small one. She was about the same mass, but with a leak, she could not maintain the pressure needed to fill all those branching digits. She could manage four simple appendages arranged evenly about her spherical night shape though. Quickly, she redistributed her mass into the right general shape.

She clustered her eyes into two large areas and raised her hairy surface sensors to their full height. Instead of matching the sand, she warmed herself to a pink color like the young one. She felt incredibly exposed, but if she hoped for the beings to notice her, she had to take the risk. It wouldn't be long before the elaw got up the courage to come close enough to scent her anyway.

The shape changing caused her to seep even more fluid into the sand. She paused, thinking how best to disguise the hairless leaking areas. Examining the small one again, she noted

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its mouth shone with wetness. In fact, the big ones had wet mouths, too! She was repulsed, realizing that this opening must serve for both eating and waste rejection. But she would use this knowledge to her advantage.

With some difficulty and discomfort, Suetork forced the leaking areas to merge. She then rippled her surface until the hairless area was below and centered between the two eye clusters.

Before the elaw had a chance to move closer, Suetork completed the new shape, but the beings ignored her. After all this, she feared they would gather their strange rock-thing and leave her to the elaw! What could she do?

Then Suetork remembered the high frequency wail the small one had made to warn the tall ones. Could she make such a sound? She stretched a section out, then sucked it in, creating a bubble like Enupten had done to deflect blows. Only instead of popping it rudely the way Enupten had done, she let the air out slowly through a small opening.

"Squeak! Squeak!" The sound came out in two short bursts. Success! The beings turned in her direction! She quickly sucked in another batch of air. "Squeak! Squeeeaakk!"

The one who had attacked her earlier approached, coming between her and the elaw. The longer she delayed the elaw, the more time Enupten's eye pieces had to harden their protective shells. So, even if she were unsuccessful in getting them to lift her out of danger, Suetork took comfort in knowing she had contributed to the survival of her group, as a good leader should.

"Squeak! Squeak!" she repeated. The pain from her wounds intensified with the intake and release of the bubbles. Her sisters undulated rainbows of concern at her from the wet blue. She couldn't signal them without disturbing her collected eyes, but it was a comfort to know they watched and cared.

Did these new beings also care for each other's survival? Suetork had to admit they had surprised her with their defense of their young one. But even elaw fought for their young when the survival of the group was at stake. With only one surviving young, these beings were probably near extinction.

The tallest one wandered off in the wrong direction. She assumed this was because that one had such short sense hairs, and they were clustered all on one end of its shape. The one holding the young on its back had much longer, and probably more capable, inputs that responded by waving in the wind. She would direct her sounds at that one. Suetork gulped another bag of air. "Squeak!" she repeated. The long-sensored one wailed a code at the tallest one, and it turned her way.

As Suetork rested for another sounding attempt, the tallest one finally spotted her. Amazingly enough, it didn't step on any of Enupten's pieces. In fact, it looked to Suetork as if the reason it took so long to reach her was it was carefully avoiding stepping on anything but sand. Either it was so ignorant it feared attack from

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the pieces, or it was saving them for later consumption. Suetork didn't know which explanation she preferred.

At any rate, the creature came very close, then folded its long shape so it was closer to the sand. It was a very complicated thing to do, and Suetork had to admire its ability to redistribute its mass that way. It then made soft sounds at her, its eyes larger than before. She assumed the sounds and eyes enlarging were its way of releasing the pressure squeezed out from the folding.

Then the long-sensored one came, now with the small one held with its two upper appendages, and also folded up to be low to the sand. They both released a lot of pressure, emitting noises and waving their upper limbs. Were they surprised to find one of their young here? Had she fooled them?

The tallest one was about to touch her when the small one squealed and puckered its mouth. The one holding it responded by giving it a small brown log resembling the base form of a dead dipput. Suetork hoped some of her sisters noticed this. It might prove useful to know how the small ones squealed when they were hungry.

The tallest one still had not touched her, and Suetork feared they would decide she wasn't one of them after all. With her leak, she could not pucker the skin she'd formed as a mouth. So, she made the same squeak as before.

In response, the beings showed their teeth! Suetork's temperature dropped as she realized her error. These beings had not ignored the food pieces scattered across the beach because they were not hungry—they ignored them because they preferred their food whole!

She must escape! But how?

Had her wounds emptied her brains? The being, alternately using one and then the other of its long appendages for support, had stepped *over* things! What a discovery! In this new shape, she could step over the hardening eye pieces of Enupten! If she arranged her mass to pool her leaking part on top, she would not even leave a trail the elaw could follow!

Suetork inhaled to build pressure in the four little appendages. Slowly, her primary mass rose above the sand. She concentrated on keeping her eyes and "mouth" on top. She tried shifting her mass to one side and lifting one appendage. Smack! She flopped to the sand, the four little appendages sticking out to the sides as before. How did the beings balance themselves on only two appendages?

She inhaled to build up pressure in the four little limbs and struggled upward again. But as she shifted her mass to one side, she wobbled and flopped back down. As she fell, her bubble of extra air squeezed out in a deeper, longer, "Squeaakkk!"

Suddenly, she was lifted into the air! The tallest one held her to its middle and ran its salty digits over her delicate pink hairs. Its mouth opened to show teeth—lots of teeth! The other one curled its mouth and showed its teeth, too! The small one squealed, waving its brown food stick toward

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her. Suetork quivered instinctively. They were hungry all right, and she was doomed!

The tallest one wrapped its upper limbs around her. Even as Suetork braced herself for absorption, she wondered how it would feel to be dissolved whole instead of scattered. Would some part of her continue, or was she to be the last Suetork? She almost envied Enupten's fate compared to her own.

She wiggled, hoping the creature might lose its grip on her. But this action only caused the being to squeeze her more tightly. The being's salty skin burned madly as it pressed against her wound, but Suetork clamped down on her response. Leaders must be brave!

While the tallest being held her tightly, the long-sensored one leaned close to inspect her. Why hadn't they absorbed her yet? She allowed herself a spot of hope that she had fooled them after all.

Her leaking had nearly stopped, so she sucked in the tender hairless skin, created a bubble, and emitted another squeak. She tried her best to imitate the young one's hunger call, to remove any doubts they might have about her being one of them.

Yes! The long-sensored one offered her a little brown food stick! As she sucked it into her "mouth," she congratulated herself on her cleverness. Not only had she fooled the creatures into lifting her out of danger, she had gotten them to feed her!

She shifted liquid to her bubble to dissolve and absorb the mass of the food. It was covered with salt crystals! Never had she tasted any prey so wonderful. Her digestive juices pulsed in ecstasy, raising her body temperature and deepening her color.

As she drifted in a state of semi-awareness, digesting the food, the tallest one folded itself and set her back down on the cold sand! Abruptly she spread her eyes and gulped air to lower her temperature. Why had they let her go?

Did they expect her to follow them? Maybe they only carried the young when they were leaking or hungry?

The winds had picked up again, and the temperature was rapidly dropping. Soon, it would be dark. The elaw had taken advantage of the tall ones being busy with her, and quickly dragged off what food they wanted. The danger gone, her sisters had begun washing ashore and changing themselves to sand balls to guard against the coming cold.

She had to make a choice: either join her sisters, or retain her new shape and go with the tall ones. Her kind's survival would be enhanced if a group of them expanded into a new territory and diversified their food sources. The taste of the brown food stick lingered inside her, firming her decision. She must go with the tall ones now. There were only three of them, and odds were good they wouldn't survive long. She would learn all she could from them, and then report back.

She signaled to her sisters and explained her plan to join the tall ones and explore the land beyond the

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dunes. They were sad, but also excited at the possibilities of new foods and the increased breeding opportunities success would bring. She appointed Vimrob as leader in case something went wrong, and then proceeded to lure the beings back to her.

She sucked in air and exhaled, "Squeak! Squeeaak!" She also tried getting up on her four little limbs to follow them, and even made two steps before falling. With practice, she could do it, but she would be better off getting them to carry her. She puckered up her hairless spot and made a pop sound like she'd seen the young one do. Oh, yes! She was getting better and better at this! The tallest one turned its two main eyes at her. She puckered up again. "Smooch!"

That did it! The tallest one folded itself and then lifted Suetork high again as it straightened out. Suetork saw that the young one rode on the back of the other tall one as before, its upper limbs wrapped around it. Imitating it, Suetork settled herself on a flat area atop one of the tallest one's upper limbs, pressing against a curve for support.

She shared heat with the tall one like she did with her sisters at night. She was pleasantly surprised how much heat it gave back! Sleeping on one of these beings would be like stretching out on warm sand. She even spread her hairless section out flat to cool off a bit, running it over one of the tall one's hairless spots. It didn't seem to mind, and Suetork enjoyed the salty taste of its skin.

After a short time, the two tall ones lifted the white hollow tube and suspended the rock thing from it between them. As they shifted their mass from side to side, the rock thing sloshed with blue deep. Suetork still didn't understand why they did this, but looked forward to figuring it out.

As the being carried her toward the dunes, Suetork considered how nice it was to not worry about elaw, the night cold, or if she would find enough food to bud the next generation of Suetorks in time to dominate the annual mating. Being treated as a young one certainly had survival value! If it turned out the beings fell to some predator before they caught more of the brown food, Suetork would simply join the feast, and then try her ruse with the winners. Eventually, she imagined her whole group would use this trick to survive and thrive as never before. ■

If a Nation expects to be ignorant and free in a state of civilization, it expects what never was and never will be . . . if we are to guard against ignorance and remain free, it is the responsibility of every American to be informed.

—Thomas Jefferson
(Submitted by Chris Casey)

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BOSE-EINSTEIN CONDENSATION: A NEW FORM OF MATTER

The fundamental particles of physics come in two distinct personality types: the individualistic *fermions* and the group-oriented *bosons*. Fermions have half-integer spins and behave as described by the Pauli exclusion principle, with only one particle allowed in each quantum state. Bosons, on the other hand, have integer spins and tend to congregate together, piling up many particles in the same quantum state.

The "groupie" tendency of bosons has recently been demonstrated in a breakthrough experiment by Carl Wieman of the University of Colorado and Eric Cornell of the National Institute for Standards and Technology and their group. They were able to cool a gas of rubidium-87 atoms to a temperature so low that thousands of atoms coalesced into the same quantum state, forming a new state of matter called a *Bose-Einstein condensate* (BEC). This column is about that work.

To understand what Bose-Einstein condensation is, we need to discuss the quantum mechanics of spin. When a massive object spins like a top or orbits like a planet, it is described in physics as having *angular momentum*. Angular momentum is said to be *conserved* because it can only be gained or lost under the influence of external forces. For example, in our Solar System angular momentum conservation keeps the planets in their orbits.

In quantum mechanics the angular momentum of a system is encoded in the system's quantum wave function. Consider, for example, an atom that has a certain definite angular momentum and wave function. Now suppose that this atom is slowly rotated through 360 degrees and brought back to the same orientation. Common sense tells us that the rotated atom is indistinguishable from the original atom and its wave function after the 360 degree rotation should be the same as the original unrotated wave function.

However, setting the rotated and unrotated wave function equal leads to a remarkable result: only atoms (and systems in general) having an angular momentum that is an integer multiple of $h/2\pi$ (Planck's constant $h = 6.626 \times 10^{-34}$ Joule seconds and $\pi = 3.14159\ldots$) will return to the same

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state after a 360 degree rotation. Therefore, all quantum systems unaffected by a 360 degree rotation must have angular momentum only in integer units of $h/2\pi$. This is called the quantization of angular momentum, and it is one of the most fundamental results of quantum mechanics.

Angular momentum quantization, when it emerged from the first formulations of quantum mechanics in the mid-1920s, was a very satisfying result that went a long way toward convincing physicists of the validity of the quantum formalism. This was because a decade earlier angular momentum quantization had been an *ad hoc* assumption used by Neils Bohr in formulating what became the Bohr model of the atom. The new quantum mechanics revealed principles that were the underpinning for Bohr's assumption.

The satisfaction did not last long. In the 1930s it was discovered that electrons violated angular momentum quantization. Electrons were found to have an irreducible angular momentum, called *spin*, of 1/2 an $h/2\pi$ unit. The electron, behaving like a tiny top that cannot be stopped from spinning, is said to be a "spin 1/2 particle." This means that the wave function of an electron does *not* come back to the same quantum state when it is rotated by 360 degrees, but only when it is rotated by 2 x 360 or 720 degrees. The same is true for protons, neutrons, and other spin 1/2 particles.

In other words, the world you view after turning your body by 360 degrees is not the same as before your rotation. All spin 1/2 particles in the Universe will have the algebraic signs of their wave functions reversed by your action. You have to make another 360 degree rotation to put the world back the way it was. There are few directly observable effects of this sign reversal, but it is nevertheless a bizarre and counterintuitive result. We have no idea where these half integer spins come from or why most fundamental particles have them, yet they do.

Our world is made of particles, some with half-integer spins and others with integer spins. Quarks and leptons, plus composite particles like protons, neutrons, and many nuclei and atoms all have half-integer spins. The integer spin particles include the force-producing exchange particles like photons, gluons, and the Z and W weakons, plus many composite particles such as mesons, nuclei, and atoms in which the half-integer spins of the components cancel or add to integer spins. The integer spin particles are called *bosons* because the statistics of their behavior in groups, called Bose-Einstein statistics, was first described by S. N. Bose and Albert Einstein. The half-integer spin particles are called *fermions* because the statistics of their behavior in groups, called Fermi-Dirac statistics, was first described by Enrico Fermi and Paul Dirac.

Fermions are highly territorial individualists. If one fermion is in a particular quantum state, then all other fermions are excluded from that state, resulting in the Pauli exclusion principle. In a universe where electrons were bosons rather than fermions, no

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life would be there to worry about it. Bosonic electrons around atoms, instead of forming into "shells" providing the outer valence electrons that make chemistry work, would pile up together in the most tightly bound inner atomic orbit, making chemistry and also life impossible. We owe our very existence to the Fermi-Dirac statistics of electrons.

Bosons, on the other hand, are gregarious groupies. If one boson is in a particular quantum state, all other bosons are "invited in" to share the same state. The more bosons that pile into the state, the stronger becomes the tendency for others to join them. In such a state, a very large number of particles will have a single quantum wave function. This is what is called a Bose-Einstein condensate. It is a new state of matter because, although predicted, it has never before been observed in an atomic system.

The grouping-tendencies of bosons are responsible for many interesting, important, and quite counterintuitive phenomena. The laser, for example, operates because photons from atomic transitions "invite" other photons to join their state as they move past, triggering an avalanche of atomic transitions and forming a beam of coherent photons in the same quantum state through the Bose-Einstein process called stimulated emission. Superconductivity is possible because bosonic pairs of spin correlated electrons move through the superconductor, inviting other pairs of electrons to join their state. Liquid helium is a superfluid because helium atoms are bosons and their tendency to group in the same state produces unusual fluid properties. The Hanbury-Brown-Twiss effect, with which photons are used to measure the sizes of nearby stars and π-mesons to measure the sizes of fireballs from ultra-relativistic heavy ion collisions (one of my areas of research), is based on the tendency of photons (spin = 1) and π-mesons (spin = 0) to group together in the same momentum state.

Up to a few months ago, despite these well-studied phenomena which depend on the grouping tendencies of bosons, the goal of producing a true Bose-Einstein condensate in a gas had eluded experimental physicists. The laser involves photons, not atoms. Superconductivity involves a few pairs of electrons interacting at relatively large distances. Superfluidity involves very closely packed and strongly interacting helium atoms, with Bose-Einstein behavior and strong scattering interactions fighting for dominance. To produce a BEC, a gas of weakly interacting bosonic molecules must be cooled to an ultra-low temperature at which the deBroglie wavelength of the molecules becomes larger than their mean spacing. The problem has been reaching such a temperature. Since the deBroglie wavelength is inversely proportional to the square root of the temperature and molecule spacing grows with temperature, a BEC can only form at a temperature below 170 nano-Kelvin (or 1.7×10^{-7} degrees Kelvin, 170 billionths of a degree above absolute zero).

Wieman and Cornell were able to produce a Bose-Einstein condensate

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of supercooled rubidium-87 atoms. Rubidium is an alkali metal from the first column of the periodic table, an atom that has a spin of 1/2 and is therefore not an obvious candidate for BEC production. However, when a gas of rubidium atoms is placed in a strong magnetic field, all spins line up and adjacent atoms combine to form spin 1 molecules that behave as integer-spin bosons.

To achieve the low temperatures needed, Wieman and Cornell used a combination of laboratory techniques: laser trapping and cooling, time-dependent magnetic trapping, and evaporative cooling. They optically trapped a gas of a few million rubidium atoms, holding them in place with an "optical molasses" of crossed laser beams. The laser frequencies were tuned to be just below the frequency of an atomic resonance for rubidium atoms. The frequency is too low for atoms at rest to absorb the laser light. Only the most rapidly moving atoms, when moving toward a laser beam, could be boosted by the Doppler shift to absorb the light. Thus the laser cooling technique selectively picks out the "hot" atoms and slows them down. This process was used to bring the gas of rubidium atoms down to a temperature of about 10^{-5} K. When this temperature was reached, a magnetic trap was switched on around the atoms and the trapping laser beams were switched off.

This magnetic trap, made with a pair of loop coils above and below the clustered atoms with oppositely directed currents, produced a "quadrupole" field that interacted with the aligned spins of the atoms to hold them in place. There is a fundamental problem, however, with a magnetic trap of this kind: it has a hole in the bottom. At the very center of the quadrupole field the magnetic field drops to zero, and there the coolest atoms can lose their spin alignment and leak out of the trap. Cornell solved this problem by adding additional coils that "stirred" the quadrupole field, moving the zero point away from the trap's center so that it circulated at the periphery of the cloud of trapped atoms in what the experimenters called "the orbit of death." As long as the atoms did not wander into the orbit of death, they remained trapped with no leaks.

Within the trap, the atoms cooled further by evaporation, with the hottest atoms escaping the trap while the cooler ones stayed behind. The cumulative effect of this process produced temperatures below 10^{-7} K, and the Bose-Einstein condensate formed. The problem then was to demonstrate that this had happened, since the BEC itself, because it is in a single quantum state, is too small to provide a direct optical image. Wieman and Cornell solved this problem by switching off the trap and watching the cloud of atoms as it expanded until it reached a size that could be imaged. They found that it expanded much slower than would any ensemble that was not in the same quantum state, and that the image was elliptical, characteristic of the orientation of the particular quantum state that had produced it. These observations pro-

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vided overwhelming evidence for the first production of a Bose-Einstein condensate. One remarkable aspect of this work is the low cost of the "tabletop" apparatus used, only about $50,000 for an experiment that will probably earn its participants a Nobel prize.

Finally, since this is a science fiction magazine, let's consider the SF aspects of this work. What is the story potential of this new technique for producing Bose-Einstein condensate? The BEC is interesting first because many atoms occupy precisely the same quantum state. This has implications for lasers, for energy storage and release, for many types of coherent behavior by a large ensemble of atoms.

Another aspect of the BEC is its small size. The size of a BEC of any number of atoms is the same as the size of one atom in the same state. This means that BEC has implications for producing ultra-compact matter. The BEC is a closet for storing atoms that is never full. In fact, the more atoms that have been stored in the BEC, the stronger is the tendency for more atoms to join them, and the strength of this "pull" increases as the factorial of the number of atoms in the condensate. The BEC is so compact and dense that, with sufficient atoms added, a mini-black hole of atomic size should form. Readers of David Brin's *Earth* and Larry Niven's "Hole Man" should be familiar with some of the implications of this.

The use of a BEC to produce a black hole in the laboratory is not likely in the near future, however. An isolated rubidium atom has an atomic radius of 3×10^{-10} meters, so a BEC of rubidium atoms should be about the same size. The mass of rubidium needed to form a black hole of this size would be 2×10^{17} kilograms, about 20 times the mass of Mars's largest moon Phobos. The BEC of Wieman and Cornell contained only a few thousand atoms of rubidium. The first BEC is a long way from any danger of black hole formation. ■

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Space will not be opened by always leaving it to another generation.

—Dr. William A. Gaubatz
(Submitted by Marianne Dyson)

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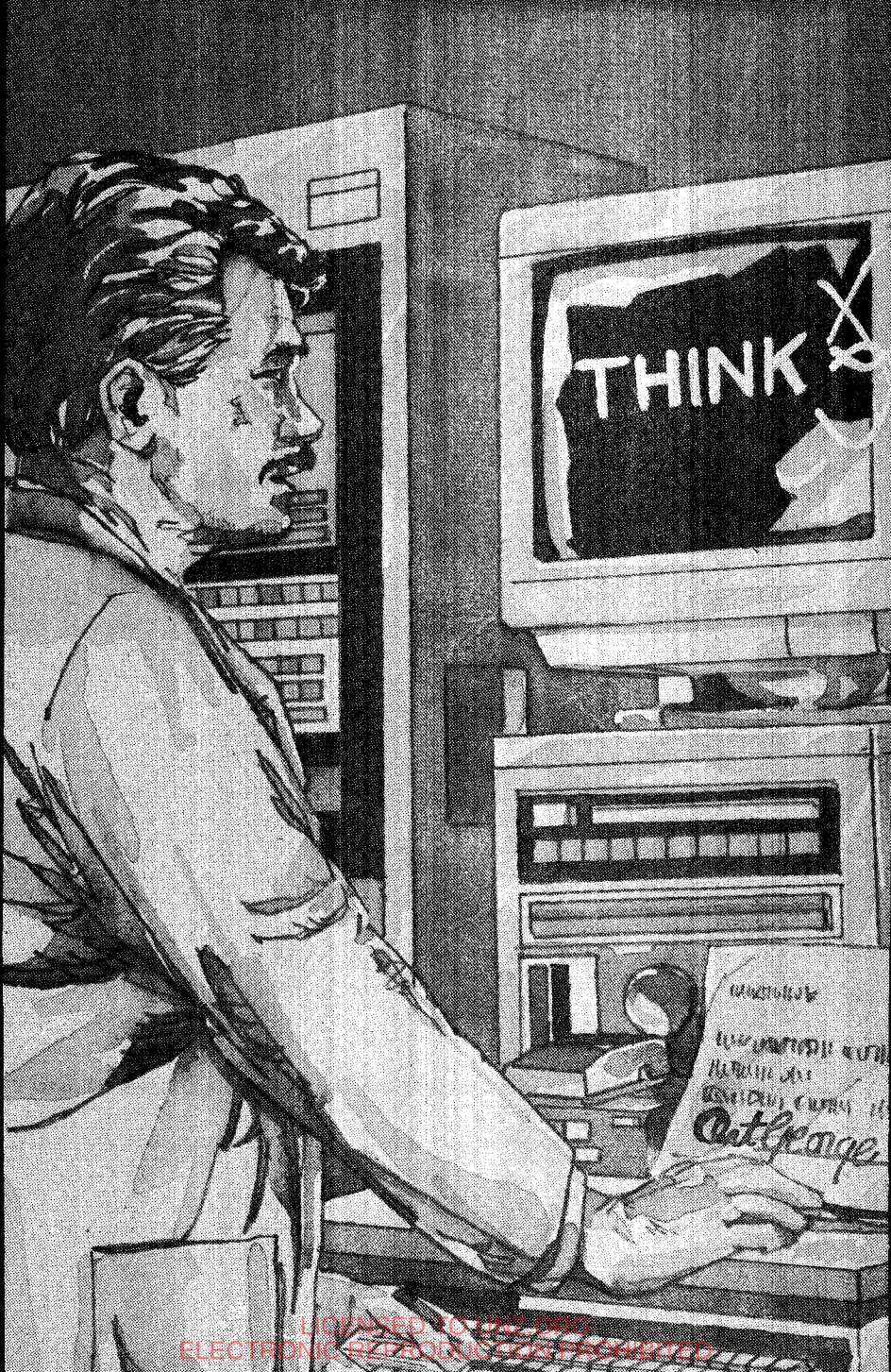

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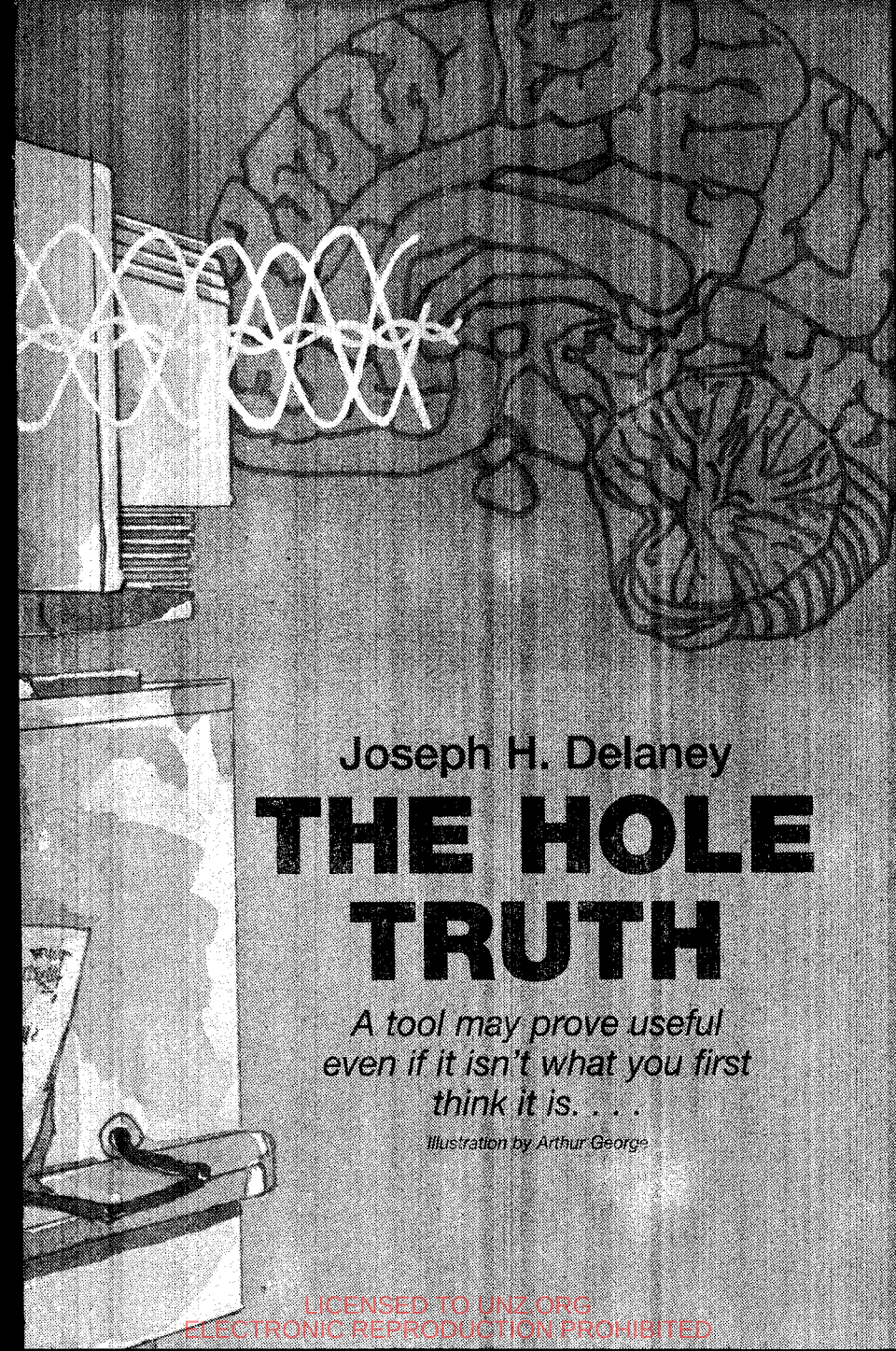

Joseph H. Delaney

THE HOLE TRUTH

A tool may prove useful even if it isn't what you first think it is. . . .

Illustration by Arthur George

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Dean Connor's office was like another world, and seemed awkwardly out of place with the rest of the campus. It was ornate, and pretentious, and it smelled musty, as though it meant to emulate the precincts of some enormously more prestigious Ivy League university.

Dr. Bryant, having been summarily summoned, entered it with enormous trepidation, with a feeling of foreboding, a portent of impending doom.

"Sit down," Connor muttered, barely looking up from a crisp, new *Wall Street Journal*. From his right hand a felt marker dangled, and on a pad next to the phone Bryant noted what he took to be a broker's number and a list of stock market symbols.

Some time passed, during which Bryant's nerves continued to rasp away, but finally Connor put the paper down, capped the marker, and pushed both it and the pad to the side of his otherwise totally uncluttered desk.

"I think it's time for you to tell me all about this test, Bryant."

Bryant's first impulse was to gasp, though he fortunately had retained the control needed to mask that. "How did you know about that?"

"I've gotten several complaints about it, Bryant. That's how. Believe me, I don't appreciate criticism from the parents of our students, especially when they're on the alumni advisory board. You've been violating the first rule of academia, Bryant, I thought you had better sense."

Bryant was completely baffled. "Complaints from parents—about a simple intelligence test? I don't understand. It isn't even a part of the curriculum, I've been developing it with my grant."

"And using your students as guinea pigs. Just where do you think you are, Bryant? This isn't Harvard, or some other school people are scared of getting thrown out of, this is Weybellowe College, the bottom of the barrel, the pits, the last resort of desperate wealthy parents and poor kids who can't afford to go anyplace else." He glared at Bryant, temper slowly building up in pitch and intensity.

Bryant was familiar with the process. So was everybody else on the faculty. With the advent of every crisis there were betting pools whose objective was to predict the exact time that Connor would stroke out.

Bryant reluctantly launched his defense. "I asked for volunteers to try it out," he said. "It was a blind study of the comparative accuracy of my test and the old standbys. The results were strictly confidential—"

"—You weren't quite careful enough then, Bryant, because you had a leak."

"Who?"

"How should I know? The point is that because of your bungling I had to spend an hour on the phone apologizing to that insufferable oaf, Frederick Van Vogt."

"I see. Well, his son was one of the volunteers, and he did miserably on all the tests, but—"

"—And his father endowed this college handsomely just so he could get in. Bryant, this family is important to Weybellowe—Vogt has three more sons, all of them as dumb as or dumber than this one. If you don't care

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about anything else you should at least be cognizant of where the money comes from that pays your salary."

Bryant was tempted—but only just—to tell Connor just how pitiful that salary was. Bryant wasn't knocking down anywhere near what Connor got. Like most of the professors here, he used his credentials at Weybellowe to get at grant money, which was what he really lived on.

Bryant's defensive posture stiffened at that thought, he was good at getting grants, and he had earned a solid reputation for delivering positive and useful results from his sideline research, so that with every successfully completed project he became a better risk and his personal academic stature grew in spite of his humble surroundings. That, he knew, was why Connor had called him in for this relatively cordial chat instead of just kicking him out.

"I don't intend to let this institution slide back into its mediocre past," Connor continued. "I've built it up to what it is today. Twenty years ago, when I came here all it was a normal school, cranking out elementary school teachers with no more imagination than sheep. Today we're a four year institution, with chairs in all the liberal arts, and some of the sciences. That's no small feat, Bryant, and I don't mind telling you that I look on anything and anybody who impugns it with a very jaundiced eye."

Now, Bryant was getting a little angry himself. "I didn't do anything to the Vogt kid. He volunteered, and he took the tests like all the other volunteers. He was in the active group and he scored on the low end of the bell—"

"—In your new test?"

"Well, yes, but—"

"And did very much better in the others?"

"Again, yes, he did. But—the other tests are old tests, which have been around for generations. Most students take them several times before they even reach college, and do better every time they repeat. In fact, that's the trouble with these old-fashioned tests, they don't test elemental intelligence except maybe on the first try, after that, they're basically memory tests. Besides, I know Vogt cheated."

"What?!"

"He wasn't the only one. Over half of each group cheated on the standard tests."

"You allowed this?!"

"Of course. I couldn't ask for a better control. Knowing this gave me a statistical spread, a small one, certainly, but its existence provided the equivalent of a third control group, because it's impossible to cheat on my test." Having established culpability on the part of the complaining student Bryant felt a little more secure.

"There's still the matter of the leak."

"Bradford and I graded the tests personally," Bryant countered. "No scores were disclosed except to the student himself. The records were then encoded blind as a part of the project data. Even if somebody got into the data file there wouldn't be any way for him to tell who scored what. No, Dean, the leak, if there was one, was a cooperative thing. The stu-

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dents must have compared their grades. I'd be interested to see who else you got complaints from. I'll bet it'll match my list of those who cheated."

"I thought you said there weren't any identifiers, Bryant."

"I'm speaking of my recollections. My memory is pretty reliable."

Connor produced a list from his desk drawer.

Bryant perused it, nodded, and replied, "Yes, I thought so." He replaced the list on Connor's desk.

"You can see these are all children of people important to this institution, Bryant. The loss of their financial support could seriously imperil its future, as well as yours." He stared blankly at Bryant.

Bryant stared calmly back.

"You're going to have to change those scores, Bryant."

"You know I can't do that, Dean. If I did a thing like that and anybody found out I'd never get another grant. And—would you want anybody on the faculty who would do that?"

Connor was caught in his bluff. Now he had to squirm out of it. "Uh—what I meant, Bryant, was that since you know they cheated you also know your data is faulty. I'd think you'd want to retest all these people and set the record straight."

"I see," Bryant replied, now convinced the suggestion had been a trap for him. Just as he was determined not to fudge his results he was equally set against retesting, which would cast similar aspersions on it. And, there was no need to. "The trouble with that idea is that it won't work, Dean. I know exactly what would happen, the scores on the old tests would improve by a predictable increment because of the past experience and the results of my test wouldn't change one iota. As I said, it's impossible to cheat on my test."

"That's a smug answer, Bryant." Connor was getting steamed again, he didn't like being told he couldn't have what he wanted.

"You say that because you don't know anything about the test, Dean. I meant it in the same sense that it's impossible to cheat in an open textbook exam. If you can legitimately go to the book and get the right answer it's not cheating.

"Of course, if you aren't smart enough to learn how to use the index, or you're too dumb to learn to read, then the open book won't help much. In my test all the subject has to be able to do is ask a computer the right questions. If he does that the computer will give him the data he needs to solve the problem within some finite quantity of time. His intrinsic intelligence is measured, not rote knowledge, and it's the time he takes, not the fact of solution, that provides the yardstick."

"Yes," Connor boomed, "but he has to know how to use the computer. Lots of people can't do that. I can't."

Bryant carefully refrained from patronizing, although the opportunity was almost irresistible. "It must have been a while since you tried it, then. Modern computers are incredibly user friendly, especially since they became independent of keyboards. Now, with a stylus or with vocal commands even a quadriplegic or a blind

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person can use them efficiently. It's like Bradford says, 'There's no excuse for computer illiteracy these days.' " There, he'd scored with a dig despite his good intentions.

Connor merely stewed and glared.

Bryant knew it was probably useless but he went on with his explanation anyway. "Bradford wrote a program that's entirely menu driven, and we've been running it on the best equipment we could get our hands on. The heart of it is a ROM disk with an entire encyclopedia on it. The program uses this in conjunction with what Bradford complains is a miserably small RAM, only 100 megabytes. Most of this is tied up in visual effects, and these are spectacular. This enabled us to construct the test as a series of physical problems for the subject to solve. One of my favorites is the manhunt."

"The what?"

"You almost feel like it's real, Dean, like if the lion or the tiger or the bear that's after you would really kill you if you got caught. Of course, there are many other versions of this—there's the burning building, the time bomb, the tidal wave, the collapsing bridge—this is what makes the test both tamperproof and accurate. Not only that, it yields a bonus, in that it's fairly easy to identify particular aptitudes among the test subjects. This is why we call it the life test, the only right answer is survival."

Connor's face, heretofore immobile, and resembling nothing so much as a pinkish stone, suddenly cracked into a smile. This soon infected his entire body as he threw his head back and exploded in a frank guffaw.

Bryant watched in fascination, wondering who the lucky person was who had this moment in the pool. He believed at the time that Connor was in fact, stroking out.

But, this lasted only an instant. Suddenly, the tables turned. "You charlatan," Connor blurted, when he could find the breath. "You've found yourself a niche, haven't you? You've invented the perfect con. Not bad, not bad at all."

Before Bryant could respond, the dean's mood darkened, and from his almost elfin image he was transmogrified, back into the ogre he always had been.

"Well, Bryant, you can do stuff like that on your own time, but not on the college's time. Weybellowe pays you to teach psychology. Hereafter, any grant you get had better be compatible with that."

Bryant started to protest. "Dean, I don't think you understand—"

"Oh yes I do, Bryant. And now that I do I think these parents will too—after I explain to them that what you're really doing is developing computer games perhaps they'll take you a little less seriously. I know I do."

"But that's—"

"Run along now, Bryant, and don't make any more trouble. If you do, you're out on your neck. I'm sure I don't have to tell you what happens to college professors who get themselves fired or that mopes like you are a glut on the market." Connor's glance was caustic.

Bryant did in fact know what happened to college professors who got

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fired. Unless they were absolute geniuses, and could prove it, they never worked in the educational field again. He didn't think Connor could justify what he seemed to be threatening to do, but that wasn't the point; Connor wouldn't have to, he would simply accuse, and Bryant would then have the laboring oar. Bryant rose, turned, and left Connor's office without another word.

Bradford's ancient Fiat clattered down the road, struggling to keep up with the rest of the traffic on the airport ramp to the freeway. For its passengers, the mood was glum.

"It's plainly no use, Chuck, Connor must have put the word out anyway. I put three weeks on the road and not only is nobody interested, I wasn't even able to get the grant renewed. Nobody is going to take anything we do seriously anymore."

"They can't all be as stupid as Connor is, Dr. Bryant. We've got something that's invaluable. It's only a question of time—"

"I don't know about that, Chuck. I have to admit this is a problem I never would have anticipated, I never dreamed anything so useful would be a hard sell. But, when you stop to think about it, there is precedent—it isn't the first idea ahead of its time. Many great developments have been publicly ridiculed, everything from the voyages of Columbus to the steam engine and the telephone."

Bradford brazenly cut in front of a tour bus whose driver was less than alert, and thus managed to reach the lane for the overpass despite the shortcomings of his laboring engine. "Those things," he remarked, "all collided head on with vested interests. This doesn't. Everybody concedes the old tests are little better than guesswork, and that not a one of them comes anywhere near ours when it comes to reliability and accuracy."

"I'm counting on that part of it to sell the military, Chuck," Bryant replied. "If there's one place where identifying aptitudes is important it's there."

"I hope they like it. If they do we can kiss Weybellowe off, designing and installing all this stuff would be a real career opportunity for us, a project of our own."

"That idea had also crossed my mind, Chuck. Believe me, I've never been too comfortable with my security dependent on a nitwit like Connor and I think it's only a question of time until he finds a way to get rid of us. I suspect he'd like it better if we moved on by ourselves but he'll step in if we hesitate."

Bradford muttered his agreement.

"They turned it down?!"

"I'm not over the shock yet, myself, Chuck. I guess I should have taken you along, maybe between the two of us. . . ."

"Don't blame yourself, Doc. It wouldn't have made any difference. DOD's experts certainly understand the technicalities, and you were there to explain the theory. I'd have been in the way."

"They said their own tests were adequate, that they'd functioned satisfactorily for fifty years and everybody

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understood how they worked. I pointed out that these were all on paper but all that got me was a blank stare. They wouldn't even provide me with test subjects, and when I said I would provide the volunteers I was told that anybody I selected could hardly be impartial. Clearly, they didn't want to look at this."

"There's precedent, Doc. Ever hear of Billy Mitchell, the guy who sank battleships with airplanes? The military response to his achievement was to convene a court martial and get rid of a nut, and so when the Japanese attacked us twenty years later we had battleships by the bushel but only four carriers in the Pacific. They gave Mitchell a medal, posthumously, of course. That was supposed to fix things."

"These are modern times, Chuck, we should be able to do better than that."

"Everybody lives in modern times, Doc, including you and me. The difference between them and us is that we're on the outside and they're on the inside. They like things just as they are because they understand them, and they don't understand what we're doing. We make them uncomfortable."

"Is that it? They're afraid of change?"

"It's a big part, Doc, but not all of it. I run into this far more than you do because computers have come so far in such a short time. The general public is intrigued but baffled. They like to play with computers but they really don't like having to trust them. The average person endures this because he hasn't got any choice, but if he had his way he'd stay where he's comfortable and count on his fingers."

"It's human nature to fear the unknown, Chuck."

"And, anybody who dabbles in the unknown. Doc, I think that pretty well defines the problem. It may well be that it isn't the unknown they really fear, but the people whom they think understand what they don't. That is very hard on the ego."

"I've been teasing up a theory of my own about that, Chuck. Tell me, why is it you've never taken the test yourself?"

"Me? Why, no particular reason, I suppose, except that I wrote the software, and—"

"Are you saying that would make the result invalid in your case?"

"No, nothing of the sort. The program should function the same for me as for anybody. Uh, how come you never took it?"

"I suspect it's the same reason why you didn't, Chuck, I'm afraid I might find out I'm not as smart as I thought I was. With the old tests there was always room for argument, the possibility of error was conceded, but now we're dealing in absolutes, absolutes with the finality of natural laws. We can no more alter our own innate intelligence than we can defy the force of gravity."

Bradford winced at the sound of that forbidden word. Frustration could do strange things, even to dedicated scientists. But he let it pass without comment. "We're better off not knowing, huh, Doc?"

"Hardly. In fact we're worse off. We're like the people who wouldn't

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take the AIDS test, the result might make us uncomfortable and we don't like that. We've been hypocritical, Chuck. Worse, we've been cowards. We won't do what we've been asking others to do, we aren't as brave as the student volunteers."

"Then, we've both got to take it, Doc. Somehow, I think that's essential to the solution. I don't think we have any chance of exploiting this thing until we do that."

"How are you going to feel if it turns out you're below normal intelligence? Can you handle that?"

"I don't know, Doc. How about you? What if you take the test and somebody you don't like tests out smarter? What if it's somebody like Connor? It's easy to be contemptuous of enemies when you can denigrate them, but what if the test shows they're markedly more intelligent than you are, what then?"

"Chuck, you're starting to scare me."

"How about we get on with it, Doc.? I think I might just be in the mood now. After awhile, who knows? Let's not give ourselves time to find excuses, let's do it now."

"Why not?" Bryant answered with a sigh of resignation.

"All right, Chuck, you're five points up scale from me, the test proves you're more intelligent than I am. Why don't I resent it?"

"I don't know, Doc. Maybe it's got something to do with the norm. Granted, I check out a little bit higher, but we're still so close to the right slope of the bell the difference is almost nothing compared to the gap between us and the left side. But, that's not entirely unexpected, is it? We wouldn't have gotten where we are if we were stupid. It's always possible that you are too intelligent to let this bother you."

"Possible," Bryant conceded thoughtfully. "Still, psychology is my field of expertise and I know reason counts for precious little when it comes to human behavior. No, Chuck, I think there's more to it than that. I think what we have here is a breakthrough, all right, but I don't think we have the complete answer. I suspect that we've really measured only one facet of intelligence."

"Now you're rationalizing, Doc, and that's a cop-out."

"I should resent that remark, Chuck. Somehow, I don't, because I know it isn't true."

"I'm sorry, Doc."

"I do resent your apparent need to apologize. I wasn't looking for pity, I. . . ."

"What's the matter?"

"I don't know."

"But, you look funny."

"Yeah!"

"Well?"

"That's because I think maybe Connor actually may have finally said something intelligent. It sure would be fun to test him."

"What did he say?"

"He accused me of developing computer games on school time. I was highly insulted, but you know, he could be right? After all, such games do test aptitudes. Some people are better at them than other people."

"Sure, Doc, but not the way we're

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better than the people at the low end on our tests. The average computer game tests motor skills, the ability to concentrate and the ability to plan ahead, and this is why practice makes the player better. No amount of practice can pump up a player's smarts."

"That *is* an interesting revelation, Chuck. However, we also test these same abilities. We have our own built-in errors. We have to eliminate them too, or we will continue to get invalid results, just as we have been doing."

"You mean, you think our data's bad?"

"Not necessarily bad, but it's imperfect. We—"

"—Perfection is unattainable, Doc. Nobody should know that better than you. We can only strive for it, but we'll never achieve it."

"We can do better than we have done."

"We can't do anything without money, and with Connor on our backs we'll have to find our volunteers elsewhere, and pay them ourselves, which means we won't eat very well. And, consider the alternative: if we don't continue the studies we'll lose this grant and it might not be so easy to get more."

"You've missed the point, Chuck. I said 'Connor had an intelligent idea,' and he did. You must know something about computer games. Tell me, how difficult is it to make and market one?"

"Idiots do it, which means we're in business," Bradford grinned. "But, what would a thing like that do to our credibility? We have to consider that?"

"I am considering it, Chuck. I think that may depend more on our choice of markets than anything else, I think we have to cater to a particular segment."

"Who?"

"I can show you better than I can tell you. Let's take a drive downtown."

"Where downtown?"

"The State Unemployment Office."

"I get it. Connor's going to fire us and we have to sign up for compensation?"

"Something like that."

"All right," Connor glared, "this is it. It was bad enough when you were just screwing up on campus, now you're running a gambling operation all over town. I think this pretty well ends both your academic careers."

"It's not gambling. Moreover, we don't run it. All we do is supply software, and we do that through a private corporation that doesn't even mention our names, much less this school's."

"Doesn't matter, people important to the school know of your connection. They don't like it. They don't like it, I don't like it. The reason I know that is I've already talked to enough of them to make sure that when your contracts come up for renewal two weeks from now that won't happen."

He paused, letting it sink in. "I said it before, I'll say it again—people who get themselves in your situation and are involuntarily terminated don't get hired elsewhere. You can keep that off your records by submitting your resignations right now, gathering up

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your garbage and getting it and yourselves off Waybellowe property. Don't worry about your students. Others are waiting to take your places. Waybellowe will get along just fine."

Connor didn't expect to get rid of the two of them without some sort of resistance, in fact, he was hoping for that, which is why he called them in to give them the axe in person. But they weren't cooperating. They just turned and looked at one another, smiled briefly, and then broke out into uncontrollable bursts of laughter.

Connor couldn't stand it. He too, underwent change. His face flushed and his blood pressure began to climb. He clenched his fists in anger, and without thinking, slammed the right one down on the glass-topped desk as hard as he could. The glass shattered, and some of the shards displaced, a few into the soft flesh of the heel of that hand.

He rose to his feet, the anger soaring to new heights. When his blood pressure followed it up the strain was too much for his mistreated circulatory system. Suddenly, with a wince of pain and a feeble squeal, his tantrum ceased involuntarily.

Connor sank back into his chair, right arm dangling limply alongside. A thin trickle of saliva flowed from the same side of his slack mouth. He muttered only gibberish from then on.

Bryant and Bradford stopped laughing as suddenly as Connor stopped talking, and stared dumbly at each other for a moment. The silence was broken when Bradford facetiously asked, "Who do you suppose won the pool?"

The business meeting of the board of directors of Gleaners, Inc. was, as always, informal. It took place in the back room of Morrie's, a less than elite bistro and eatery on the wrong side of the tracks, frequented mostly by impecunious college students and transients. The fare was tolerable, and reasonable, but not fancy.

Bryant, as chairman of the board, opened the meeting with a toast. "To Lefty Connor, without whose cooperation this entire operation would have flopped."

Down the hatch went five mugs of Dad's Root Beer, each fortified by a shot of scotch. This combination, which sounded revolting, was uncommonly palatable, though it didn't work with just any old root beer. Just about any kind of scotch would do but the root beer had to be the real stuff.

"Now, then," Bryant continued, grabbing a slice of the pizza the waiter had just delivered, "what's the score, Donohoo?"

Bill Donohoo was the company treasurer. Also, he managed the local office of the State Unemployment Commission. "We made $8,700.00 off the machines last month," he announced, "all of which was used to expand to new locations, including six other cities throughout this state. Fees for testing brought in another $23,000.00, all of which will be distributed to the stockholders and board members as salaries and to reimburse for expenses."

"Good for you, Bill," Bradford shouted, a little louder than he intended, being on his second round of scotch and root beer. "Eating is the

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hardest habit I ever tried to break."

"Stay sober, Chuck, you have to give the progress report. I'm through, so you're next."

"It's a formal occasion," Bradford replied, "so I'll stand, if I can." He struggled to his feet, grabbed himself a slice of the rapidly disappearing pizza, and announced, "We placed 113 people in more or less responsible jobs last month. I'm particularly pleased to announce that eight of these were scientific positions filled by people without degrees in the discipline for which they were hired, and that five of these competed successfully against people who did have such degrees."

There was a round of applause. Bradford used the interval to wolf down his pizza and reach for more. "Our star testee was Junius Brown, a transient originally from Bone Gap, Illinois. Junius is now third shift engineer at the Bolton Textile plant here in Waybellowe. I have to say I never expected to see a perfect score on spatial relationship comprehension but Junius came within a hair, all with only six years of schooling—"

"—And the plant manager tells me they haven't had fifteen minutes downtime on the line since he took over third shift," Donohoo interrupted.

"I was just gonna say that," Bradford added glumly. "Uh, that's all." He quickly sat down, just as the waiter entered with a fresh pizza.

"I'd ask the secretary to read the minutes of the last meeting, only I happen to know she didn't take any."

"I'm not going to take any this time, either, Don," the secretary replied. Judy Ivnik really was a secretary, Bryant's old secretary from when he was a professor at the college. "I'm waiting for you to finish the old business so we can take up some new things."

"As far as I can tell, we *are* finished, thanks to your negligence. OK, how about it? Is there any new business? I'd like to stop talking and start eating, too, you know."

"I'll make my motion," Judy announced. "The motion is that we double the prize for high scores and make it a dollar, and that we also cut the fee for playing from a dime to a nickel."

She turned to face blank stares from Bryant and Bradford, the only two of the five of them presently unemployed.

Anticipating their probable comments she continued, "Believe it or not, there will be substantially more people playing if we do this. To some it might even make the difference. I figured it out, and it's clear that increasing the volume will substantially increase the number who play, but it won't even come close to doubling the number of winners. Therefore, we'll save a little bit there, and in time, we'll be even again on our own revenue."

"You've got figures?"

"Well, they're in my head, Chuck, but—"

"—OK, then I'll accept them, and I second your motion. But, let me add a thought; at the moment, we're taking hits on rewards because we let the smart people play over and over again. Now, there's nothing basically wrong with that except that it's re-

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dundant for us and it defeats our basic purpose. For them, all it proves is that in that one category they can win over and over again.

"So, what I propose is to amend the motion, to change the rules so that if a winner plays again he has to take a different test. That way, he gets another chance at a prize and we get new data. With this new data we'll be able to tell just how broad a person's genius really is."

"I can buy that, Chuck," Bryant added. "How about you, Bill? Would it screw up your operation any?"

"Probably not," Donohoo answered. "If anything, it would make it easier for my people to evaluate the applicant. We'd have a better idea who to send him to. And since our system is already trunked into Gleaners's there wouldn't be any additional load. For Gleaners there'd be more records, of course. I think, to be fair to the winners, we ought to be able to tell them why they're barred from competition."

"The employers are already doing that, Bill. It's part of the hiring process. Some of these guys have been so browbeaten by society they're convinced they're inferior. It's a real boost to self-esteem to know they're not."

"And that worries me, too," Donohoo replied, almost defensively. "What are we going to do when word finally leaks out, when some of these formerly 'elite' people have to face the truth that it's they who are inferior? That's going to hurt, Don, that's the bunch in power."

"I won't argue with you there, Bill. I've put considerable time into the problem myself. They best I can say is that they have it coming. And they do. As long as man has been man, raw ability has never been allowed to be the regulating mechanism it should have been. There have always been ways for the inferior or mediocre to cheat. The weak have always combined to pull down the mighty.

"A human being can be an idiot in all other respects but still be clever enough to deceive gullible people into thinking he is something more, just because his ancestors were achievers. The feudal system, which dominated Europe for a thousand years, was built on that proposition, and every modern society is still controlled by a dynasty of some kind.

"What's generally overlooked is that there are categories of stupidity just as there are of genius. Stupidity is no more universal than genius is. This is why Albert Einstein, who sometimes got lost on the way to his office, was still capable of working out mathematical problems nobody else could. Nobody's good at everything and nobody's bad at everything.

"We haven't by any means developed the ultimate intelligence test. We've only just started, barely scratched the surface. And you know what I think? I think it'll probably work out much different than we thought, for the very reasons I just mentioned. What we really have here, I suspect, is not so much an intelligence test, *per se,* but a practical way of putting all our round, square, triangular, trapezoidal and other

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shaped pegs into the proper holes."

"Sounds like maybe at last we've got the hole truth," Bradford replied, a noticeable slur in his voice. He wolfed down another slice of pizza and chased it with another mug of the high octane root beer.

Bryant winced when he saw that his next challenge was under construction; they'd come in Bradford's car. Bradford stood six-four and weighed 260 pounds. Taking his keys away from him was going to be a chore unless. . . . It works in politics, he mused, then smiled broadly and said "You're dry, Chuck, let me pour you another drink."

Bradford held out his mug, and reaching for more food, failed to note that this one was more than half scotch.

You're a little bit brighter than me, Chuck, he said to himself, *but until you develop a test for sneakiness you're still gonna keep on losing*. Suddenly, Bryant realized that here was man's real need. Until a human being appeared who could indeed find a way to produce the truth, each time, every time for everybody, all other research into man's behavior was a waste of time.

I'll get him started on it the instant he sobers up, Bryant resolved. ■

IN TIMES TO COME

Our April issue has one of those "stand-alone" covers, by one of *Analog*'s favorite artists, Vincent Di Fate. The lead story is "The Copyright Notice Case," a new Phil D'Amato mystery by Paul Levinson. If you remember D'Amato's first appearance, in "The Chronology Protection Case," you know he tends to attract cases a bit outside a private detective's routine, and this one is no exception. It takes a while even to realize what kind of a case it is, and even then there are *big* questions of communication—and jurisdiction.

Our other April stories, by such folk as Doug Larsen, Sarah Zettel, and Brian C. Coad, include a couple with just a touch of seasonal appropriateness. Kelvin Throop even seems to have broken into the office again, and will appear in a couple of different capacities. We'll also have Part 3 of Charles Sheffield and Jerry Pournelle's *Higher Education*, and a fact article by Gregory L. Matloff proposing an expedition to interstellar space that might be worthwhile and feasible in the relatively near future. It seems you don't have to go all the way to another star to find anything worth looking at. . . .

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Probability Zero

Ron L. Figgins

COMMUNICATIONS FAILURE

"Hansen, you'd better have some answers!" Brad Mitchell, VP of Operations, bellowed. "Since *you* introduced Eliminall our stock has plummeted, and it's still falling!"

David Hansen, Advanced Agricultural Engineering's Senior Research Director, glanced nervously at the angry faces of the executive committee around the huge, Synthi-Oak table. Clearing his throat, he began, "Uhm . . . gentlemen, I believe we've isolated the problem.

"As you know, Eliminall is the market's first selective, wide-spectrum, nanoengineered herbicide and bio-nutritional enhancer. The Eliminall solution not only destroys unwanted weeds, but rapidly breaks them down, at a *molecular* level, into nutrients the target crop can easily use."

A hand rose in the back of the room. "You mean, Eliminall is a weed and feed."

Laymen! Hansen thought, cringing. Putting on his best smile, he said, "An excellent analogy! But by using specifically programmed nanoengineered machines, Eliminall is a very *intelligent* weed and feed."

"Hansen, we know all that!" Mitchell interrupted. "Why isn't it working?"

A look of surprise shot across Hansen's face. "Uh, it's not that Eliminall isn't working. The problem is that it works *too* well!" Dimming the room's lights, he slipped a Holo-disk from his pocket and inserted it into the table's projector slot. A surreal figure appeared hovering above them. It resembled a patchwork cross between a bulldozer, vacuum cleaner, and several other machines.

"This is the HP, uhm . . . Hunter-Processor unit, that makes up the Eliminall. A single ounce of the matrix contains billions of these." The next slide displayed a split screen image. On one side, line after line of computer code leaped into view, the other showed a complex electrical schematic.

"Here are the culprits," Hansen declared, pointing to an obscure area in the middle of the code. "The Filter-Discriminator and the Quantum Sig-

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nal Processor circuit are having an unanticipated fourth level interaction. It's causing a failure between their communication protocols and so certain materials, which should be ignored by the HP's, are being targeted and, uh, well . . . eliminated! Fortunately, the interaction range is very narrow. We were really quite lucky to have discovered it at all."

"Lucky!" Mitchell screamed. "The media are having a field day! 'Ninety Minutes' claims Eliminall is causing major chromosome damage all over the midwest!"

Hansen blinked nervously. "But I've gone over the field reports in detail! The flaw only affects cotton."

The words were barely out of his mouth when Mitchell leaped to his feet, his face as red as the synthetic sugar beets Hansen had developed last year. "Hansen, don't you realize half our business is with *cotton* growers all over this country!" Mitchell paused for breath, but before he could continue, Hansen pressed on.

"But it doesn't attack all cotton. It ignores cotton *plants* just as it's programmed to do. It only attacks *processed* cotton fibers; and then only certain weaves and colors. For some reason, it seems to have a special liking for blue. I'm certain we can correct the problem. In fact, the new HP program will be ready for insertion in a few more days."

Silence filled the room while the committee considered Hansen's report. Finally, somewhat mollified, Mitchell sat back in his chair looking puzzled. "From what you've just described, I don't understand why there was such a panic. But the news reports clearly mentioned severe gene damage."

Hansen had been afraid this would come up. "There was a *second* communications failure," he stated quietly. "As I said earlier, the defect gave the Eliminall a special affinity for certain cotton fabrics, blue denim in particular."

"Hansen," Mitchell fumed, "get to the point! What was the second failure?"

Hesitantly, he advanced to his final slide. Wearing nothing but a faded leather hat and worn work boots, a hulking male figure, large, somewhat overweight, and embarrassingly *bare*, leaped into view. Conspicuously absent were his cotton coveralls. Around his feet, a few tattered strips of faded blue cloth were the only evidence that they had ever existed.

"What the reporter *meant* to say, was *jean* damage!"

Armadillos make affectionate pets, if you need affection that much.

—Will Cuppy

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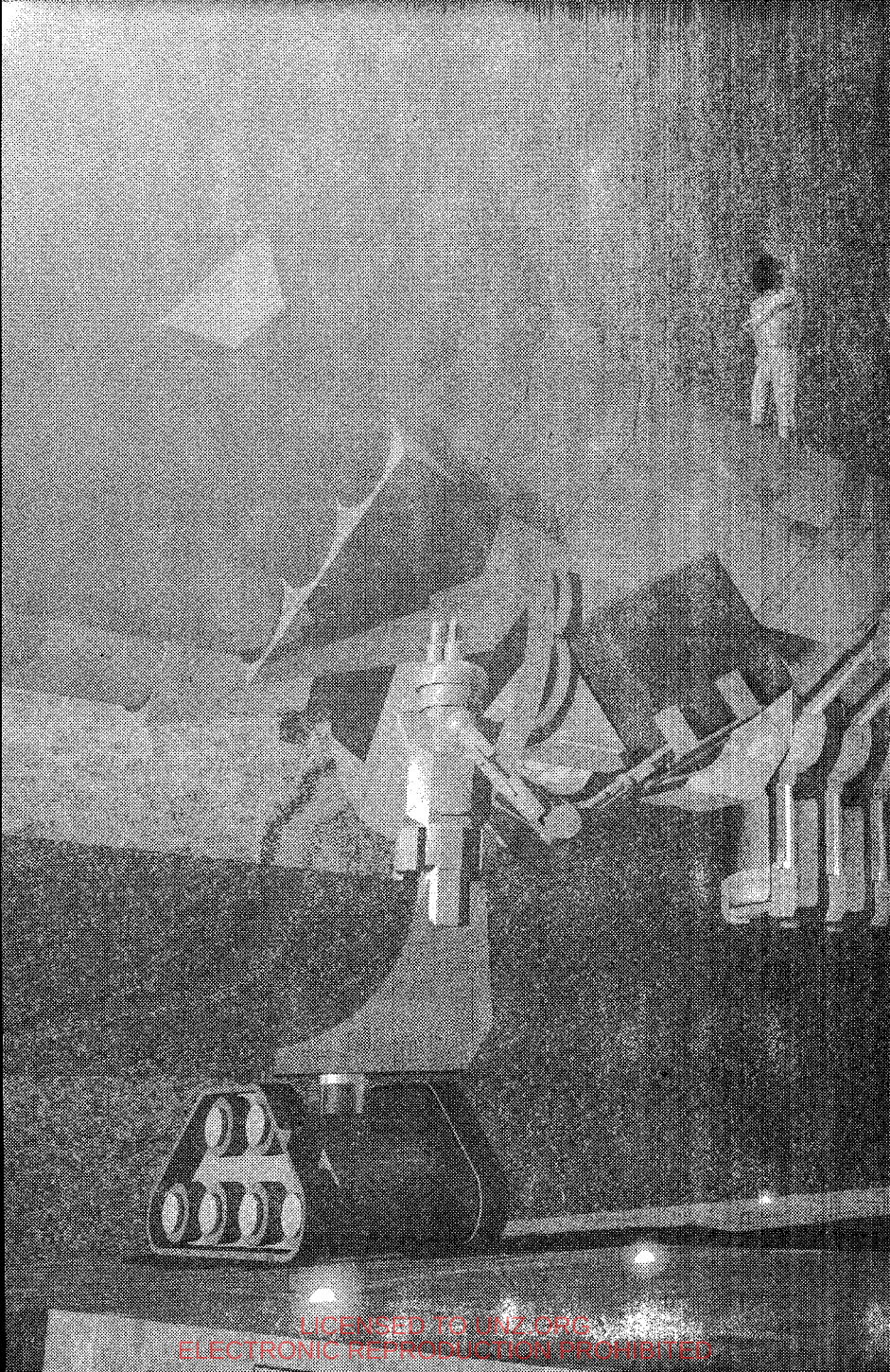

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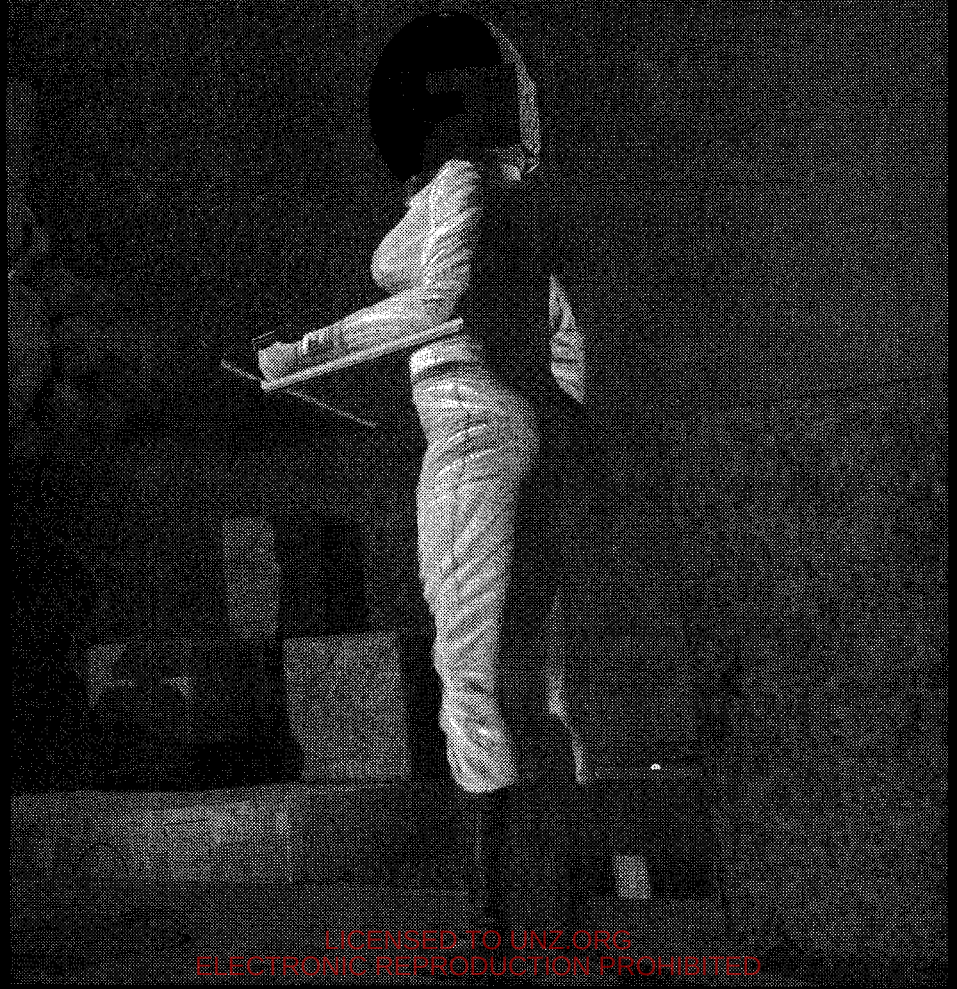
Part Two of Four

Charles Sheffield & Jerry Pournelle

HIGHER EDUCATION

Education is painful because it means change—and there's nothing like a new, unforgiving environment to make that happen!

Illustration by George H. Krauter



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SYNOPSIS

Rick Luban *is a bored sixteen-year-old trapped within an education system that does not care if he succeeds or fails. In another two years he and his classmates will graduate, despite the fact that they can read only short and simple words and have negligible knowledge of science, mathematics, history, literature, or any other field of study. The school's teachers, lacking all authority over the students, have given up on education and merely try to keep the classroom under some minimal level of control.*

Rick's life changes when a new teacher, **Willis Preebane,** *shows up to teach the civics class. Rick, egged on by his friends, sets up a water booby trap for Preebane—and catches instead a member of the Board of Education who happens to be a congresswoman.*

The usual mild penalties for student misbehavior no longer apply. The congresswoman insists that Rick be expelled at once from the school. He is forced to leave but is afraid to go home, since his mother and stepfather will lose the education payment that they receive as long as he stays in school.

He remains sitting outside the school, until he is approached by one of his teachers, **Mr. Hamel.** *Hamel points out just how Rick got into trouble, and how stupidly he has behaved; but Hamel does feel some sympathy, and is willing to try to help. He gives Rick an address on the other side of town, where a job might be available.*

Rick goes there the same evening, and is given a battery of aptitude tests that are forbidden in the public school system. He passes, and is offered a trainee position with Vanguard Mining and Refining. However, the job is not anywhere on Earth. Rick will be trained to mine the Asteroid Belt, out between the orbits of Mars and Jupiter. Before he can go, he will need parental permission. In fact, while he is away all parental authority will legally be transferred to Vanguard Mining.

He returns home to tell his mother and stepfather the news, and is depressed by their reaction. All they seem to care about is how much money they will receive for giving permission for him to go with Vanguard. The very next morning he has packed his few belongings and is on his way to New Mexico, where additional tests and training will be conducted.

Rick quickly learns that his new job is not going to be easy. For one thing, he will have to compete with other new recruits. Not every one of the newcomers will be accepted and sent into space. The first people he meets, **Vido Valdez** *and* **Alice Klein,** *prove to be smart and tough and highly competitive. The New Mexico training is physically and mentally demanding, and before it is over Rick and Vido have had a fight. It ends when a staff member of the training camp breaks it up—but Vido vows that it will not really be over until he says so.*

The successful recruits, including Rick, Vido, Alice, and another pushy

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boy named **Chick Teazle,** *head off for the next stage of training, out in space. It will take place on a facility known as CM-2, in translunar orbit. On the flight up from the surface of Earth, Rick meets* **Deedee Mao,** *a tough and aggressive girl from another training camp. They get into an argument, which ends abruptly when they encounter free-fall for the first time and are too busy fighting nausea to fight with each other.*

As their ship approaches CM-2, **Jigger Tait,** *an experienced space miner who is on his way back to the Asteroid Belt from Earth, points out something else that no one has told Rick and Deedee before: Vanguard Mining is not without competition. There is another company, Avant Mining, that is aggressive, fast-growing, and a real threat to Vanguard. Jigger shows them an Avant Mining ship, returning from the Asteroid Belt.*

The transit craft arrives at last at CM-2. As Rick boards that facility, he catches sight of Earth. It is seven hundred thousand kilometers away; to Rick's lonely and homesick eyes it seems more like seven hundred million.

Part II

CHAPTER SIX

"Let me introduce myself." The man was plump and balding, with fleshy cheeks and drooping jowls. "I'm Turkey Gossage, chief of the training program on CM-2. You can think of me as the principal here—the head teacher. You don't know it yet, but I'm the best thing that ever happened to you."

Rick had taken a position near the back. He craned for a better look. The man in front of the group was dressed in a black tank top and jeans rather than the standard jacket and slacks. He scowled aggressively as he stared at them, but his blue eyes were sparkling. There had been a low general mutter from the group, and he was reacting to it.

"You heard me, sweethearts? The *best* thing. So if you got something to say, get it off your chest now."

No one spoke.

"You, sweetheart." Gossage pointed a finger at a woman in the front row. "I see your mouth moving, but I don't hear you. Don't whisper. Tell all of us."

"Don't you call me sweetheart!" It was Deedee, not much to Rick's surprise. "You can't do that."

"I can't, eh?" Gossage was grinning, but his neck and jowls turned red as turkey wattles. It was suddenly obvious how he got his nickname. "Why not?"

"Because it's degrading, and it's insulting. It's also sexually discriminatory. Do it one more time, and I'll take you to court." Deedee paused.

"You mean you'll sue me?" Gossage grinned again, but now it was unexpectedly friendly. "Sweetheart, that word is music to my ears. It proves we've got innocent new blood out here on CM-2, and it leads me straight in to what I have to say to all of you. Let's get a few things out of the way right now. First, forget the sexual discrimination talk. I call *everyone* sweetheart. You, and Bluebeard standing next to you"—that was Chick Tea-

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zle—"and the one at the back with the shitface grin on his chops."

Gossage was looking right at Rick. Rick stopped smiling. He saw Vido Valdez in front of him turning to smirk. Next to Vido, Alice Klein stared at and right through Rick.

"Far as I'm concerned," Gossage went on, "you're *all* sweethearts 'til you prove otherwise. As for suing me, good luck to you. You're not on sue-'em-all Earth now. We got exactly two lawyers out beyond the Moon, and they're up to their asses in mineral depletion allowances and tax codes. If you can afford their time, you don't belong here. And if you did manage to sue, you'd lose for reasons that I'll go into in a minute. So tell me what else is on your mind. You were angry before I ever called you sweetheart."

Deedee shook her head. It was another youth in the second row, one of the East Coast additions to Rick's group, who spoke up.

"What's this *teacher* bullshit? I done with school two month ago. Nuthin' 'bout school in anythin' anybody said to me."

"I see. What's your name?"

"Cokie Mulligan."

"All right, Cokie Mulligan. Nothing about school in anything anybody said to you. Right. You *read* your contract, did you? The one that you and your parents or guardians signed."

"Sure I did."

"The whole thing?—including the fine print."

Mulligan hesitated. "Yes."

"Then you noticed the place where it says that Vanguard Mining, and in particular its authorized instructors—people like me—are *in loco parentis* to you for the duration of your contract."

"Don't know what that means."

"*In loco parentis* means *in place of your parents*." Turkey Gossage smiled horribly at Mulligan. "So now I'm like your daddy and your mommy, all rolled up into one. And I'm going to take better care of you than they ever did."

Mulligan shook his head. "Maybe. But I don't want no teacher, an' I'm not goin' to no dumb school. I hate school and I'm done with school. I never signed up for that."

There was a general mutter of agreement from everyone in the group.

"I see." Turkey Gossage turned, floated across to a chair facing the front of the room, and straddled it with his forearms folded along the back. "What we have here, I suspect, is a simple failure to communicate. It's that hated word, *school*, isn't it? It suggests the wrong thing to all of you, and I shouldn't have used it.

"So let's agree that this isn't a school. Let's say it's a survival course for off-Earth mining operations. The Belt is a dangerous place. You can screw up big time out there, eat vacuum, O/D on radiation, blow yourself up, get flattened by an ore crusher, get stranded and starve to death. No legal liability for Vanguard Mining—read your contract. But Vanguard doesn't want you dead, because we already have an investment in you. You think all those tests you took don't cost money? So it's my job to make sure that by the time you leave here

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you know how to *avoid* killing yourself. That means learning a few new rules. Anybody object to the idea of *surviving?"*

Rick shook his head and glanced around at the others. Everyone was doing the same.

"Good." The smile never left Turkey Gossage's face. "Now we get down to details. I'm going to give you assignments that have to be completed before bedtime. But before we talk about them I want to talk about *you*. I'm sure you all think you're hot-shot and special and smarter than most people. And maybe you actually are—otherwise you wouldn't be here at all. But smart or not, at the moment you're still zeroes. No skills means no value.

"Before we're through here, that will change. You'll have skills. You'll have value. You'll have a *reason* to think you're hot-shot and special. And it all starts with the assignments. Today it will be reading. All right?"

Nods all around.

"Just one thing." Turkey Gossage was deliberately casual. "I said *reading,* and I meant reading. By you. Not with a reading machine. There will be times out in the Belt where a knowledge of complex instructions is vital and no electronic readers are available. So you have to be able to read. I'll let you in on a big secret, something you'd never be told in an Earth school: reading is easy! Practically everyone can learn to read with a bit of effort. All of you can, or you wouldn't be here. And we won't go too fast at first. Short words, easy sentences."

There was a stir at the back of the class. A short-haired and overweight blonde girl was moving toward the door.

"Now where are you going?" Gossage did not raise his voice. "Leaving us already?"

She turned angrily at the doorway. "Yes, I am."

"What's your name?"

"I'm Gladys de Witt. I didn't read none when I was in school, and I'm damned if I'm going to start now I'm out of it. Go screw yourself, Gossage. You think you're the boss, but you're not. You can't stop me leaving. I seen the contract. I don't have to stay. It says you can't use violence on me, neither."

"That's quite true. I can't prevent any one of you from leaving. I can't be violent with you—though we might disagree on what constitutes violence. And I can't make you complete your assignments." Gossage nodded slowly. "Very true. All I can do, Gladys de Witt, is explain these to you." He held up a handful of small pink cards. "They are meal vouchers. You need one to obtain food from the cafeteria service system. When you complete your assignment satisfactorily—by this evening, or tomorrow morning, or tomorrow midday, or whenever—you will receive one voucher. But if you fail to complete your assignment to my satisfaction, you will not."

"You can't do that to me!"

"I'm afraid I can. Read your contract. Vanguard Mining, *in loco parentis,* decides the manner and extent of trainee nutrition. Now, Gladys. Are you going to leave? Or would you like to stay here with the rest of the trainees while I explain today's assign-

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ment? Dinner is lasagna with mushrooms, peppers, and garlic bread. The choice is yours."

Turkey Gossage could smile and coax with the best of them, but he was one tough son-of-a-bitch. His language would have horrified Mr. Hamel, and he hadn't been kidding about the food voucher policy. After a few missed meals and a taste of CM-2 gruel, even the toughest and most ornery—and hungriest—trainee came into angry line.

Rick observed closely, then put Turkey Gossage into his "handle with care" category. What he couldn't understand, though, was how Gossage had found himself such a pleasant, easygoing—and droolingly sexy—assistant.

Gina Styan was a graduate trainee from three years back, returned for two months to work with Gossage on CM-2 before she went to her post on the newest of the thirty-eight Belt mines. She had a figure that made Juanita Cesaro and Monkey Cruse look like boys, clear dark skin, and short-cropped black hair that emphasized delicate bone structure and high cheekbones. Those, plus what Rick read as an unmistakable interest in her brown eyes whenever she looked at him, bristled the hair on the back of his neck. The sight of her made him catch his breath.

She had the hots for him. He was sure of it. All it would take was a quiet place and an opportunity.

Which seemed to be exactly what CM-2 was designed not to provide. It was just as well that Deedee Mao's liftoff invitation to Cabin Twenty-eight had been bogus, because it now proved to be impossible. She shared her tiny cabin with three other trainees, including Monkey Cruse. Rick would love to have heard the conversations in there, but when it came to accommodation he was no better off. His cabin had five recruits in it, including Cokie Mulligan who snored like a saw in free-fall, though he swore he hadn't when he was back on Earth.

Vido Valdez, thank goodness, was two cabins along, bunked with Chick Teazle and a couple of East Coasters. Vido and Rick still glared at each other whenever they met, but apparently Valdez was willing to see their feud damped down—at least for the time being.

Privacy was no better during work periods. The recruits were never out of each other's sight, except when they were busy on work assignments. Then they were permitted the privacy of a single small cubicle. After the first week Rick suspected Turkey Gossage of doing that on purpose. When the only way to be alone was to sit in a little room by yourself and pretend to study, you found yourself actually studying part of the time out of sheer boredom. Almost against his will, Rick found himself starting to read. He still wasn't good, and he resented every word, but within a couple of weeks he'd have beaten everybody in his old class and most of his fellow trainees. He was in no hurry to rush on ahead. After reading, Turkey Gossage threatened pure and applied mathematics—"the queen of the sciences, the

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high spot of all your training," as he put it, without convincing anyone. And before they could graduate, every one of them had to write a letter home.

"What the hell for?" Chick Teazle protested. "My mother hates my guts—and anyway, she can't read."

"I'm sure she loves you dearly." The smile never left Turkey's face. "She'll find a reader, or get somebody else to read it to her. But even if she doesn't, even if she tears it up and throws it straight down the chute, that doesn't let you off the hook. You still have to write—and I have to be able to read it."

Rick had started a letter three times in the first two weeks, and scrapped the result after a couple of sentences. What was he supposed to say? That he preferred it out here to being with his mother and Mick? Even if that was true, Rick suspected that Turkey Gossage wouldn't let a letter go out that way. The problem of *what* to write was going to be as difficult as the writing itself.

Rick crumpled up his fourth shot at writing, threw it away, and stared at the cubicle wall. Never mind letters to his mother. They wouldn't make him feel any less horny. The big problem now was Gina Styan. How was he ever going to make out with her if they were never alone?

A possible answer came in the third week, when the pure theory of space operations gave way to practical experience. All the trainees had become accustomed to free-fall, so nausea was a thing of the past. But manual work in space was another matter. That took lots of practice.

And practice they were going to get, in assignments that Turkey Gossage described as "Manual coordination and control in a weightless environment." A euphemism, as Rick soon discovered, for unpaid hard labor.

Weightless environment. Moving things around in space, where an object didn't weigh anything, sounded easy as breathing. Nothing to it. Jigger Tait, staying a while on CM-2 with Turkey Gossage before shipping to the Belt again, assured Rick as much. Then he and Rick went together to the deep interior of CM-2 to clear one of the chambers. They moved massive pilings and metal I-beams and irregular chunks of rock.

After four hours of that Rick ached in every bone. His burdens might have no weight, but they still possessed *inertia.* And inertia was *worse* than weight. In fact, it was twice as bad. Back on Earth, once you had lifted something you could just let it drop and gravity would do the rest. Here you had to work to start a rock moving, then put in just as much labor to stop it.

But Jigger had not been lying. He did the work effortlessly. It *was* easy as breathing—for him.

Rick wondered how many other half-truths and hidden catches were tucked away in the Vanguard Mining training program. Turkey Gossage was sticking to his policy on the meal vouchers. After two bowls of cold and sticky oatmeal, Rick had finally handed in his last assignment. He had received a meal ticket just before he left with Jigger. It sat burning a hole in his

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pocket while his stomach growled in protest. He could hardly wait for the word to quit.

But when Jigger Tait told him they were done for the day, Rick still had enough energy and curiosity to notice something when they emerged through the airlock from the planetoid's stony interior. It was a different lock from their entry point and next to it sat another small chamber. It was like no other structure that Rick had seen. There were flat, solid, windowless walls and a massive close-fitting door.

Rick's question about it produced no more than a shrug and a dismissive "Historical interest only," from Jigger. Tait would have continued back around the planetoid toward the training facility quarters, but Rick stopped in front of him and swung open the heavy door.

"Hey! Padded floor and walls. What's the deal?"

"Bolt-hole." Jigger followed him inside. The interior lights had come on automatically. "Before the mining work produced the deep interior tunnels, the miners always faced a radiation danger. Our suits aren't enough to protect us."

"Solar flares?"

"Yeah." Jigger stared at Rick. "I thought you couldn't read."

"Videos. Show it as a standard hazard for space travel."

"Well, for once they got it right. If you're out on the surface of an asteroid and a big flare hits, you have three choices: you can move to the interior tunnels, if there are any, or you can head for a special shielded chamber like this one. Me, I'll take this any day. Your own air, see, the interior fills by itself when the door is locked. And there's plenty of reserves of food and drink. Stay here for a week if you had to."

"But there's no airlock."

"There is on the inside. That was put in later. When they built this they figured anyone coming in from space might be in one hell of a hurry."

"You said there are three choices?"

"Sure." Jigger was already moving back through the thick door. "You can stay outside and fry if you want to. Freedom of choice. Isn't that what people back on Earth are all so proud of?"

"Freedom to *die?*"

"Sure. Most basic right of all." Jigger started around the planetoid, swinging easily along on the fixed network of cables. "Hell, you should be free to die when you want, where you want, how you want. If you're not, your body and your life don't belong to you at all. They belong to your keepers."

"You can die any way you want to?"

"Sure I can. Anyone works for Vanguard Mining has that right. But dying is a right, no more. It's not an *obligation*. So watch your step, Rick. Space is more dangerous than you think."

CHAPTER SEVEN

Rick remembered Jigger Tait's words about the dangers of space, more or less. But what he thought about a lot more in the next few days was that shielded chamber. Radiation-proof—and soundproof. He visited it a couple more times when he had no other duties. Thick walls, padded

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floor, and tight-fitting door. Total privacy. Just what he needed.

It took four days before he could trade with Monkey Cruse for her next one-on-one training session with Gina Styan in the interior of CM-2. Fortunately Monkey had her own hot ideas about Jigger Tait. She didn't tell Rick what this particular training was for, and Rick didn't ask. He'd be willing to move a lot of rocks for a chance at Gina.

This time his job turned out to be both easier and harder than manual labor. Rick had to learn to operate remote-controlled cutting equipment, and Gina proved to be a hell of a tough teacher. She ran him through scores of operating steps again and again, watching him with that slightly mocking, sexy and intimate look on her face whenever he messed up a sequence.

"There's a lot to this." Rick felt obliged to defend himself when the session ended with the cutter under his control waltzing wildly sideways to gouge a hole in the tunnel side wall. "How long did it take you to remember all the variations?"

"I'm not sure I ever did."

"You have a pictorial prompt in your suit helmet? Then why in hell didn't you give me one?"

"No prompt." Gina waved a small red book at Rick. "The control steps are in here, along with a lot of other stuff. But it's all in words and formulas. Once you can read well—"

"This is really dumb. A few simple pictures, that's all it would take."

"You think so? Listen to this, then you tell me how you would put it into pictures. 'Pressure equalization between old and new drilling is best achieved by releasing stored air into the evacuated chamber. The cutting equipment normally produces a straight cylindrical cavity three meters in diameter, so the volume to be filled is simply $2.25.\pi.L$ cubic meters, where L is the length of the new drilled tunnel in meters.' You know what π is?"

"I think so. I'm not sure." Rick was actually quite sure. Sure he didn't.

"It's a mathematical constant. Draw me a picture of *that* if you can. Do you know its value?"

Rick shook his head. This wasn't going the way he had imagined it, but he'd bide his time. Let Gina feel superior for the moment. She would find out soon enough who was the real boss.

"Why should I bother to know any of that math stuff? If I ever need it I'll pull it up on a calculator."

"π is equal to 3.14159." She didn't seem to have heard him. "That's to six significant figures. It's as accurate as you'll probably ever need unless you get into orbit work, then you'll want it to twelve. You'll have the value of π engraved on your brain stem and your butt before you leave CM-2, along with a lot of other numbers you've never heard of yet. And while we're at it, let me tell you what happens to a calculator or an electronic prompter during a blow-out or a big radiation storm: they die, or they become totally unreliable. But this"—Gina held up the red book—"it can stand more radiation, heat, and cold than you can. By the time a book like this became

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unusable, you or I would be long dead."

She tucked the book into a pocket on her suit. "You'll learn, Ricky boy. Let's go."

Rick had learned, at least some things. He had spent most of his few free hours studying and committing to memory the network of passages and chambers that crisscrossed the interior of CM-2. Without saying anything to Gina he headed for the surface along a particular set of passages. He emerged, just as planned, right beside the shielded chamber. The door was as he had left it, slightly ajar.

He stopped when he came to it, and led the way inside.

"You ever been in one of these?"

"Ages ago. This, or one just like it." Gina had followed him and was glancing around her with no particular interest. "I don't know why they keep this place in working order. It has no uses since the interior was excavated."

"It does." Rick swung the heavy door into position and pressed the sealing button. Interior lights came on at once and there was a hiss of released air. He went across and checked that the inner door was also sealed.

"Not needed for radiation protection," he went on, "but it has other uses." He took off his suit helmet and gestured to Gina to do the same.

"You're wasting air." But Gina did not sound much concerned by that, and she followed Rick's lead and removed her own helmet. "Other uses? Like what?"

"Like this." Rick had been sizing up their positions and rehearsing his own next action. He knew the moves and he was pretty experienced, but that had been back on Earth. He had to do things differently in free-fall.

The smart thing was to make a first move that he knew he could manage. He was close to the chamber wall. He kicked off from it, drove hard across the room, and pinned Gina against the opposite wall. He had to use both arms and legs to hold her there, but they finished face to face.

"Gina." He spoke in a whisper, though he could have screamed and no one else would have heard a thing. "Gina, you're really something special. Let's get out of these dumb suits and have some fun."

He tried to kiss her, but she turned her head away.

"Dammit, Rick, that's enough fooling. And it's not funny. Let me go."

He almost did. Then he remembered Screw Savage's advice to him and Hoss. "*No* never means no with a woman. They say it because they like to play hard to get, but they really want it bad as you do. You gotta ignore what they *say* and keep chargin'. Go for the gold!"

Rick moved his left arm quickly to turn Gina's head back toward him, pressed his mouth to hers, and started to give her a French kiss. His right hand felt at the same time for her breast.

It was as though he had pressed a starter button. As his fingers met her left nipple through the resilient material of the suit, her right knee pistoned up between his legs. It hit him squarely in the crotch like a bony hammer.

Rick gasped and curled up into a

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ball, hanging in midair. He was sure that the blow had burst his testicles and driven them right back inside his body. He vaguely heard Gina speak through his fog of pain.

"You little shit! *Nobody* does that to me, *ever.* Apologize." She had him by the ear, pulling it off his head. "Apologize, right now, or I'll really hurt you."

Rick was curled up, forehead close to his knees. He could hardly breathe, and he certainly couldn't apologize. But if he didn't, she might do the same thing to him again.

"Sorry!" It was more a gasp than a word. "Sorry."

"I don't know what made you think I'd be interested in a semi-literate oaf like you, but here's news: I'm not."

She let go of his ear, then clapped his helmet back onto his head hard enough to make his ears ring. While he hung dizzy and helpless, she flipped his suit seals into position.

"You can find your own way back, dummy, or you can die trying. I don't much care which."

Rick heard the inner door slam shut and the airlock cycling. He tried to lift his head to see if Gina had gone, until a worse worry took over. Nausea swept through him. He felt ready to vomit—inside his suit.

He swallowed hard, closed his eyes, and fought the urge. The spasm slowly faded. By the time it was over his forehead was beaded with cold sweat and the sickness had been replaced by an agonizing throbbing in his belly and groin.

Fifteen minutes passed before he felt strong enough to leave the chamber. Then it was a miserable splay-legged crawl back to the training facilities. He paused before entering.

What had Gina told Turkey Gossage? Surely, the whole horrible episode. Rick was done for. He was going to be kicked out of this place, just as he had been kicked out of school. And where could he go now? Back to join the Pool on Earth?

Might as well get it over with. He couldn't hang around outside forever, and there was no way he could avoid the rage of Turkey Gossage.

Rick eased his way out of his suit and limped to Turkey's office. He didn't see anyone on the way, and he almost changed his mind when he was right at the entrance. But Gossage had already seen him on the threshold and waved him in.

"You took your time." Gossage nodded to Rick and at once returned his attention to the screen in front of him. "I didn't think you'd make it before I closed for the day. Help yourself to a meal voucher."

Rick, tensed and ready for a storm of anger, stared at Gossage open-mouthed. "What did Gina say?"

Turkey really looked at Rick for the first time. "Say? Why, what do you think she said? She said you did well. I know you rammed the wall with the cutter at the end, but Gina said that the test she gave you was harder than anything in the standard course. So you passed. Now, go and eat before I change my mind."

Rick grabbed the voucher and left before Gossage could ask him anything. But he didn't feel in the least like eating, and still less like going into the cafeteria where he might have to

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face Gina. He was sore, exhausted, and bewildered. He started for his cabin, knowing that he needed rest. Then he visualized Cokie Mulligan and the other trainees, watching him limp in and starting with their questions.

He couldn't stand that, either. Where could he go? The study cubicles were always crowded at this time of day.

The only place he could think of was the gym. It was a bit of a mystery why CM-2 even had a gym, because so far as he knew no one ever went there. But the region had light centrifugal gravity, and there were showers. He could examine and bathe his bruised and tender balls, stretch out on a couch, and not move until it was time to wake up and use his meal voucher for breakfast.

He dragged his way toward the outer circle of the station where the gym was located, thankful that it was a time when few people were about. Safe inside the bathhouse, he removed all his clothes and took a warm bath. He examined himself closely. So far as he could tell everything down there was perfectly normal. He didn't even seem to be swollen, though it felt that way from the inside. Finally he went into the shower, set the water temperature as hot as he could stand, and simply let the stream run over his head and back for a long time.

By the time he dried himself and put on a change of clothing he was feeling human again. He emerged from the shower area and stopped. The gym was no longer deserted. Jigger Tait was running laps, round and round the inside of the big hi-g wheel. He must have been there for a while, because his blue T-shirt was stained with sweat.

He nodded down at Rick when he caught sight of him and ran around the hoop of the track toward him. "Want to join me?"

Rick shook his head and started toward the exit. But he couldn't help moving in an awkward bow-legged fashion.

"You all right?" Jigger stepped closer.

"Yeah. I'm all right."

"You sure don't look it. That's a John Wayne walk—like you got a bad case of hemorrhoids, or you just took a dump in your pants. What happened?"

"I just—" Rick paused. He didn't have a lie in his head. Anyway, Jigger would find out soon enough, along with everybody else. He sighed. "I just did something really dumb."

And then, when Jigger said not a word, it all came spilling out. It seemed even worse in retelling than in reality. Jigger stood and listened in silence, the sweat cooling on his moon face and steam rising from his damp T-shirt. It was only after Rick told how he had made his move on Gina, and she had kneed him in the testicles, that Jigger shook his head and said, "Wish I'd been there."

"You'd have stopped her?"

"No. I'd have broken you in two." Jigger grabbed Rick by the arm and led him to a pair of rowing-machines, the only place where the two of them could sit down facing each other. "How old are you, kid?"

"Sixteen."

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"Thought so. Know how old Gina is?"

"Nineteen?"

"She's twenty-two. You're like a baby to her. Hell, you *are* a baby. Back in school you probably felt like a real big shot—I know I did. I'd had girls, I'd busted teachers, the whole bit. But to Gina a kid from Earth is still in diapers. I'd say each year in space, 'specially in the Belt, is like three on Earth. You were a little kid making a pass at a grown-up."

"But she didn't report it to Gossage. And she *passed* me on the test I took."

"Sure she did, if you did well on it. Why wouldn't she? You didn't really upset her. How'd you feel if a ten-year-old girl came on strong to you? You'd think it was ludicrous. And you were being tested for proficiency, not maturity. Anyway, believe it or not, Gina likes you. If she didn't she'd have ripped your balls off and stuffed them down your throat. She'd have got away with it, too. What ever made you think for one second that she might be interested in you?"

"She looked at me like she was really fond of me."

"Yeah. Know why? Because you remind her of her kid brother. He's back on Earth and going nowhere, just the way she was before she tripped up and was sent out here. Gina admits it, she used to be a real tearaway. Her parents couldn't do a damn thing with her. But her brother's less of a rebel, and she's afraid he'll just stick in school to the end and finish up in the Pool."

"You don't think she'll tell anyone about what I did?"

"Don't see why she should. But I'll talk to her and make sure."

"Will she listen to you?"

"I think so." Jigger stared at Rick for a second, his head to one side. "You're not too observant, are you? I mean, you've never noticed that Gina and me are an item, have been for a year and a half. That's why I came to CM-2 instead of heading right out for the Belt. That's why I know about her, and what a hellcat she used to be, and all about her kid brother."

Rick gazed at Jigger in horror. He had just remembered what Jigger said about breaking him in two. "I didn't know—I didn't notice. I'm sorry. I mean, if I'd had any idea that you two—"

"You know now. Nothing wrong with feeling horny, either—it means you're physically adjusting to space. But stick to trainees. And don't forget one other thing. California where you came from has the strongest laws in the known Universe against sexual harassment and rape, but they still don't work worth a damn. Out here we do things differently. A woman is taught a few tricks so she can look after herself. Deedee and Monkey and Gladys are getting special training you'll never hear about. All the girls are being taught how to look after themselves. Remember that, if you want to keep your balls." Jigger stood up from the rowing machine, came across, and patted Rick on the shoulder. "And while your jewels are still sore, use what happened with Gina to remind you of one other thing: If you want to survive in space, it's not enough to be able to read and write and calculate. You have

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to learn to *notice things*—the sort of stuff you won't find in any book."

Rick skulked for a week. He hid away in the privacy of the study cubicles, until finally and inevitably he had the dreaded face-to-face meeting with Gina. She came into the cafeteria with a group of trainees while he was taking a hurried meal.

Rick froze. But her casual greeting suggested that nothing unusual had ever happened between them. Rick breathed a prayer of thanks and decided that he could return to the normal harassed life of a trainee on CM-2.

It didn't work out that way. He didn't hide away any more from Gina, but soon he had even less free time than usual, as two new things happened in quick succession.

The first came when he ran into Jigger Tait, and the big man was again on his way for a session in the gym.

"Every day," said Jigger in answer to Rick's question. "So does Gina, and so does Turkey Gossage."

"But why? None of you is fat or anything."

"No. But we're in space, in a low-*g* environment. Regular exercise is absolutely essential, otherwise you suffer calcium loss. Keep that up for a while and your bones get weak. When that happens it's a real bugger to get back to normal."

"But nobody's making *us* exercise."

"They will, before you're finished. You've only been excused because Turkey likes trainees to get their space legs before he lets them loose in the gym. Otherwise they run into walls or fall over things or tear muscles using the exercise equipment." Jigger studied Rick as they moved along side by side. "You seem to handle space pretty good. Take a bit of advice from me. Get a head start right now, and use the gym regular. The sooner you do, the less chance you'll have of long-term space problems."

Rick nodded, but he might have ignored Jigger if he hadn't run into Vido Valdez half an hour later. They converged in the quiet study area. Exactly one cubicle was vacant.

They stood together in front of the sliding door, with Rick a few inches in front. "Guess we could take turns," he said. "You—"

He didn't finish the sentence. Vido sideswiped him from behind. Rick went sprawling forward into the wall, and before he could get up Vido was inside and had closed the door.

"Bastard!" Rick tugged at the handle, then hammered hard on the panel. "Open up!"

"Go screw yourself."

"I was here first." When Vido did not answer, Rick hammered on the door again. "Let me in."

There was a chorus of complaints from the neighboring cubicles. "Get the hell out of here!" "Shut the racket!" "Hey, this is a *quiet area.*" And then, from a piercing female voice that Rick recognized as Gladys de Witt's: "Stop your screaming, Luban, and bugger off—or we'll call Turkey Gossage."

Rick tugged one more time at the door. It did not budge. In an absolute fury he banged again, then hurried away to another series of complaints and abuse.

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It ain't over 'til I say it's over.

It wasn't over between him and Vido, far from it. Rick rubbed at his shoulder. Valdez was strong, and the blow from that muscular arm had hurt. If another fight was coming—and it seemed to be—Rick would get creamed again. Unless he could somehow change the odds.

He recalled Jigger's advice. Though it was the last thing in the world—or out of it—that he felt like doing, he headed for the region where the gym was located. He couldn't make himself bigger and heavier than Vido, but maybe he could make himself harder and fitter.

He changed into shorts and a T-shirt and went through to the hooped track with its centrifugal gravity. Someone was already there, running with an easy, floating style that appeared totally effortless. He halted. If that was Gina, and she misunderstood. . . .

But it wasn't. It was Alice Klein, dressed in a black singlet and the briefest of black shorts. Rick waited until she came past where he was standing, then accelerated to the point where he could step onto the moving track. He ran until he was at her side.

"Mind if I join you?"

She turned her head and gave him that smile that never got above her mouth. Rick took it as an OK, and matched his stride to hers. Within a minute he realized there might be another reason for that smile. She was moving *fast*—and not even breathing hard. Low *g* must suit her; she seemed to float along as though this was her natural element. Out here her thin limbs looked graceful, even beautiful.

Well, he wasn't going to put up with another fiasco, like the one on the treadmill. Instead of trying for more conversation, he looked straight ahead, lengthened his stride to one more natural to his height and the reduced gravity, and concentrated all his attention on running. The track was about a hundred meters long, forming a hoop that rotated at constant speed about its center. Centrifugal force produced an effective gravity maybe a third of Earth's. As you ran, the path ahead seemed to rise all the time in front of you; yet you always felt as though you were on level ground.

A blue strip across the floor of the hoop marked the beginning of each lap. After the first two, Rick began to look for the line of blue and count as they passed it. Three, four, five. . . .

When the count reached twenty laps, he wondered how long he would be able to keep it up. He stole a sideways glance at Alice, trying to look nonchalant—and found that she had turned her head at the same moment.

"That's it for me," she said, and slowed her pace. "But you don't have to stop on my account."

She was laughing at him, Rick felt sure of it. There was a sly, satisfied tone in her voice. He slowed too, trying not to gasp for air. Still she did not seem to be out of breath.

"How long have you been doing this?" he wheezed, as they stepped together off the rotating track.

"This? You mean running? Since the

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third day after we got here." And then, as though reading his mind, "You'll find it gets easier fast, once you do it regularly. I had real trouble the first few days."

Instead of setting a course for the showers she was heading to the equipment room. Rick followed her. The rowing machines that he and Jigger Tait had used were right near the door, and Rick hadn't even taken a good look at the rest of the place. He watched as Alice Klein sat down on a padded seat and strapped herself in. She reached up to a horizontal bar and pulled it down with some effort to chest level. Rick had seen similar workout equipment back on Earth, but here there were differences. On Earth, a machine like this made use of gravity. You pulled down, and a cable ran up from the bar, over a pulley, and raised a set of weights. As you allowed the bar to go back up, the weights were lowered.

Here, though, in negligible gravity, weights would not do the trick (Turkey Gossage didn't even want the trainees to use the word *weight;* he said the right term to use in space was *mass*). This exercise machine had an arrangement of multiple springs, so that as you pulled the bar it exerted a constant upward pressure all the way down for you to work against.

"You don't get fit watching," said Alice, after half a dozen pull-downs. She did not look at him, but Rick moved forward to sit at the next machine. Then there was another twenty minutes of silence, as he learned that his upper body was even more in need of conditioning than his legs and lungs.

Finally Alice allowed her bar to go all the way up to its rest position and came to stand next to Rick. She studied the settings on his machine and shook her head.

"I can't match you there. You have twice my muscle power, and you always will."

"And you'll always be able to run me into the ground."

"Could be. That's life. Horses for courses."

She nodded at Rick and headed for the showers, leaving him to wonder what on Earth she meant by that last remark. In his whole life he had never even seen a live horse. Where Alice Klein came from, in the Dakota Black Hills, life must be very different from a southern California big city.

What had *she* done, to get herself kicked out of school and sent up here with Vanguard Mining?

He doubted that he was going to find out any time soon. Alice Klein was not the sort of person you could easily ask a question like that.

CHAPTER EIGHT

Rick did not exactly *avoid* Vido Valdez for the next two weeks. He preferred to think that he was so impossibly busy that they did not run into each other. With the increasing difficulty of the assignments set by Turkey Gossage and Rick's self-imposed work-out schedule, there was no time to do more than study, exercise, and collapse exhausted into bed.

On the other hand, Rick knew that he was not going any place where he was likely to run into Vido. That made

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him secretly uncomfortable with himself.

He kept exercising, but he didn't feel either fitter or stronger. He was surprised when after ten days he went to the gym and again found Alice Klein there, and they ran thirty silent laps side by side with Rick hardly aware of either his legs or his breathing. Apparently physical fitness crept up on you.

After they had showered they walked back to the school area together, discussing the latest horror that Turkey Gossage was trying to inflict on them: *algebra.* It produced the greatest outburst of eloquence that Rick had ever seen in Alice.

"Useless!" she said. "Why does he make us learn it? I'll never get the hang of all his a's and b's and x's. It's not as though you would ever run into a situation where you might want to use it."

Rick was not quite so sure. Certainly, he could see zero value in the equations that Turkey made them set up and solve. But Turkey Gossage did not strike Rick as someone likely to make anybody learn things just for the sake of learning. Every activity on CM-2 seemed to have a defined goal.

"It's like the ladder thing this morning," Alice went on. "He told us how long it was and how far the end was from the wall, and he asked us to find how high up you could reach with it. I don't know how to do that, but it doesn't matter. Out here you don't need a ladder. You just jump!"

She was trying to justify the fact that she didn't know how to solve the problem. Rick was pretty sure that he did. It raised a real question: Should he explain to her what she had to do to get an answer? Just as in the physical tests back in New Mexico, the trainees were in competition with each other. Some were going to fail. If Rick helped Alice Klein, or anyone else, might he be ruining his own chances?

On the other hand, Alice had encouraged him to run and to work out with the exercise equipment. She didn't have to do that.

Rick sighed. "The ladder isn't really the point," he said. "Turkey put it that way, but really it's just an equation we have to set up and solve. All you need is that formula we did the other day about the sides of triangles with a right angle. See, think of the ladder as the long side of the triangle. . . ."

Alice listened in silence as Rick explained and they walked to the study cubicles. "You're right," she said at last. "That does it. But it doesn't change my basic point. You can solve dumb problems with algebra, but it isn't something anybody needs in the real world. Thanks anyway."

She left, leaving Rick to go on into one of the cubicles, close the door, and wonder. He also couldn't see any practical use for what they were being taught. But Vanguard Mining was not an organization to waste money. More importantly, you did what you were told on CM-2 if you wanted to eat and rest.

He bent over the day's assignments. His own trouble spot wasn't the math, it was the reading. He was sure he was falling behind. Why wasn't anything written the way it sounded?

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Why were words that were spelled almost the same, and ought to sound almost the same, completely different when you spoke them?

bough—cow; cough—off; rough—stuff; though—owe; thought—taut; through—few.

Rick, hard at work, heard the cubicle door slide open behind him. He turned, suddenly nervous, then relaxed. It was only Monkey. She had lost a few pounds since arriving on CM-2, and it suited her. The uniform showed off her new and slimmer figure, and with her thinner face her brown eyes looked gigantic.

She slid the door closed behind her. Rick wasn't worried—but he was puzzled. Perpetually horny or not, Monkey had shown not the slightest interest in him. It went both ways. He knew she was attractive, but she didn't light his fires the way a couple of the other trainees did. Attraction between the sexes was a total mystery, but it was a definite reality.

Which left the mystery of what Monkey was doing in Rick's cubicle. Study cubicles were supposed to be *private,* not the place for social chitchat.

Monkey answered that at once, by setting the print-out sheet she was holding down on the working surface in front of Rick. It showed an array of blank squares, with writing alongside. She touched the sheet. "I got no idea what any of this means."

"Yeah? Well what the hell has that got to do with—"

"Alice says you're real good at explaining math stuff. She says you just helped her."

"So what if I did? What you think I am, some free service center? I got my own work and my own problems."

"If you'd help me, I'd pay you back." Monkey saw the look on Rick's face, and shook her head. "I'm not talking about anything like *that.* I'd help you with your assignments."

"What makes you think I need any help?"

"I got a look at your history paper. You trying to tell me you *don't* need help?" Monkey smiled. "I like that stuff, and I know it. I can show you. So what do you say?"

Rick had already taken a look at the sheet that she had placed in front of him. It was one of Turkey Gossage's damnable math crossword puzzles. You had clues for across and down, but the answers were all numbers. There was enough information provided to fill in the whole thing—just—but to do that you had to work enough logical connections between the clues to pin down unique digital values for each square.

Rick wasn't about to admit it, to Monkey or anyone else, but he *liked* doing this stuff. It wasn't hard to nod grudgingly and say, "Sit next to me, where we can both see the sheet. I'm not going to do this for you. But I'll show you how to do it for yourself."

"That's what I need. I won't be sitting where I can ask you during the tests." Monkey squeezed onto the seat next to Rick. The cubicles were intended for solo study, and it was a tight fit. Rick felt a warm hip press against his. When he moved his right hand to the sheet, his elbow brushed her breast.

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"Sorry. Couldn't help it."

"That's all right. The pleasure's mine." Monkey's reply sounded like a come-on, but there was no flirtation in her voice. Her attention was on the clue that Rick was pointing to.

"Now, you can certainly do this one," he said. "It's straight arithmetic. All you have to do is add the two numbers, and that's the answer to D Across."

"Yeah. Wish we had a calculator."

"Wish on. You know Turkey." Rick controlled his impatience as Monkey took pencil and paper and slowly and patiently worked out the answer. "Good. Now you do F Across the same way, and that will give you some of the numbers you need for getting a handle on E Down."

"Right." She started to calculate again. Slowly, at glacial speed, answers came and were transferred to the crossword sheet. After fifteen minutes, fewer than half the numbers of the square had been filled in. Monkey seemed pleased. Rick wasn't. He knew from experience that the tougher half lay ahead.

They were puzzling over one of the clues, heads close and bodies touching all the way from hips to shoulders, when a sound came from the door behind them. Rick was concentrating and didn't move. It wasn't just that Monkey's proposed answer was *wrong*. It was more like totally baffling. How could anybody produce such a weird result and somehow dream it might be right? So when the door opened he merely said, "Yeah? What you want?"

There were no words at first, just a gasp of disbelief. And then, "Deedee said you was in here. I was sure she was lying."

Rick swung his body as far as he could, but he was jammed too close to Monkey. He craned his head around. It was Vido Valdez, his face twisted with shock.

"Vido." Monkey squirmed against Rick, struggling to get up and off the seat. "You don't understand. You've got it all wrong."

"I understand what I see. You in here, wriggling and rubbing your tits all over him. What you think I am, a dummy?" Vido lifted his arm as though he would strike Monkey, then lowered it. He looked ready to cry. "Just get out of here," he said in a quiet, dead voice. "You bitch, after all you said to me. I don't even want to talk to you."

"Vido, we weren't—"

Valdez was not listening. He had moved forward to stand in front of Rick and was glaring down at him. "You're too scared to fight, so you thought you'd get back at me some other way."

"Monkey came here asking me to help her. We didn't do anything."

"You been avoiding me, I know that. You're too much of a coward to face me. Well, you get to face me now." Vido reached out and hauled Rick backward off the seat. "You think you're good with women, let's see how you do with men."

The cubicle was small and cramped. Rick knew one thing for certain: if he and Vido started a fight in here, he was doomed. There would be no space to dodge and weave, and Valdez

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was far stronger. As Vido reached forward, Rick ducked low and dived for the cubicle door. He landed on all fours in the narrow corridor and started to scramble away along it.

"No you don't." Vido was rushing after him. Rick rose to his feet and turned to face the blind charge. He got in one good punch on the side of Vido's head, enough to divert the other's forward momentum away from him, then he ran away as fast as he could in the other direction. He had been lucky with that first punch, but the corridor was too narrow to maneuver. If he was to stand any chance at all against Vido he needed lots more space.

Doors were opening on both sides of the corridor as Rick zoomed along it. Other trainees were coming out to see what the noise was. With any luck they would slow Vido's progress.

When Rick came to the gym it was deserted. He wasn't sure whether that made him glad or sad. Jigger Tait might have halted Vido and stopped the fight, but that would have solved nothing. Vido was so mad he would just wait and jump Rick the next chance he got.

Locking Vido out would be no better. It had to be here and now.

Rick turned. Vido was running toward him. Unlike on his first rush, his hands were up to protect himself. As he came close he reached out to grab Rick in a bear hug.

Rather than dodging to left or right, Rick jumped straight up. He rose about fifteen feet to the ceiling, reached his target of one of the exercise brackets, and grabbed it to check his movement. He hung easily, supporting himself with two fingers of one hand. Suddenly he realized that the dynamics of a fight in low *g* were completely different—and to his advantage. He had weeks of experience with the exercise equipment, and he was pretty sure that Vido had hardly any.

He looked down. "You want me, dum-dum? Then come up and get me."

Valdez produced a choked grunt of rage, crouched, and jumped at Rick. It was exactly what Rick wanted him to do. Once his feet left the ground he could do nothing to change his direction. He came floating upward.

Rick waited, bracing his back against the ceiling. When Vido was within reach, flailing his arms and legs helplessly, Rick kicked out hard with both feet. The heel of his right foot caught Vido on the jaw, while his left foot set the other's body spinning. Vido crashed shoulder-first against the hard ceiling, rebounded, and floated slowly back down. His raised arms and head smacked into the padded floor. Then he did not move.

Was he unconscious, or just faking it?

Rick could not tell. Rather than repeating Vido's mistake and finding himself helpless in midair, he crabbed along ceiling and wall using the exercise brackets. Within a few seconds he reached the floor and could walk warily over to where Vido was still lying face-down.

Unconsciousness could be faked; blood could not. Rick saw the stream

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of red oozing from Vido's scalp and nose and suddenly felt scared. He had meant to put his enemy out of action, not kill him. He bent to turn Vido over, wondering what to do next.

He did not have to make that decision. Gina Styan suddenly appeared at his side. "Get back to your dorm," she said curtly. "You've done enough for one day."

"I didn't—" Rick began. But he went unheard, because Monkey came into the gym, screamed, and ran across to cradle Vido's head in her arms.

"You've killed him." She was glaring up at Rick, her brown face flushed darker with blood. "He's dead."

"He's not dead." Rick had seen Vido blink and move his feet. But Monkey screamed again. "You've killed him!"

Gina caught Rick's eye and jerked her head. "Out of here. This will be easier on everybody if you're not around."

Easier on Rick, that was for sure. He saw a dozen other trainees crowding into the gym. They were all staring at Vido's bloodied head, then frowning accusingly at Rick.

He pushed his way through them without a word and headed for the dorm. His daily assignments were not finished, but there was no way he could work on them now. He was too agitated.

Back at his empty dorm he threw himself onto his bed. If he had just told Alice Klein to go take a jump instead of explaining her problem to her, none of this would have happened. He would be quietly at work on his study tasks. And now look at him. Vido was sure he had been screwing around with Monkey, when he hadn't laid a finger on her. Everybody else believed he had knocked the shit out of Vido, when actually all he had been doing was defending himself. And because he wasn't getting his work done, he would be forcing down lumpy oatmeal tomorrow.

So much for trying to help people. Rick closed his eyes. Next time he would know better.

CHAPTER NINE

Early next morning before classes began, Rick was summoned to Turkey Gossage's office. Sure that he was in trouble, he was in no hurry to get there yet afraid of being late. He finally arrived a few minutes ahead of time.

Gossage nodded him to a seat on the other side of the circular table that he used as a desk. He went on studying a monitor, invisible to Rick. He was muttering to himself, until at last he looked up.

"I guess you think you're a real hotshot."

"I never meant to hurt him." When Turkey looked blank, Rick blundered on. "I didn't. I really didn't want to fight at all."

"Oh, *that*." Turkey waved his hand in a dismissive gesture. "I wasn't talking about that. I had a meeting with Valdez last night, and he says the whole thing was his fault."

"*His* fault!"

"You got hearing problems? Your physical didn't show it. You heard me, his fault. He says he came across a sit-

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uation, misinterpreted it, and blew his lid. You were just defending yourself. You want to disagree with that?"

"Well, no. But I'm surprised." Suddenly Rick felt like a coward.

"That's permitted. Thank him when you see him. Now let's start over." But Turkey had to pause, because there was another knock on the door. "Come in."

It was Deedee Mao, arriving to the appointed second. Turkey waved her to a chair next to Rick. "I'll ask you the same thing I just tried to ask Luban," he said. "I guess you think you're a real hot-shot?"

"No." Deedee glanced at Rick, convinced that he must have said something about her, but he shook his head.

"So you don't know, either?" Turkey went on.

Rick looked at Deedee. She seemed just as puzzled as he was. "I don't," she said.

"Then I guess I'll have to tell you." Gossage was studying their faces. "The pair of you are sitting near the top of the trainee heap, along with a couple of others. You and Chick Teazle and Gladys de Witt are all doing well. Keep going this way, and you'll graduate."

Rick's pleasure at that surprising news didn't last too long, because Turkey hadn't finished and he had a diabolical look of glee on his face.

"Naturally," he said, "since you're such hot-shots we want you to have a specially good chance to make a mess of things. So for the pair of you, the training course just moved beyond supervised instruction. Tomorrow morning you'll be partners on a practical exercise in space ore mining. And I promise you, it won't be easy. I suggest you spend the rest of today studying the problem. You have until the close of the work day tomorrow to complete the assignment."

Rick and Deedee exchanged grimaces. They had pretty much avoided each other since their first liftoff into orbit. Now they were supposed to cooperate—even depend on each other.

"Studying together." Gossage had read their faces. "The more you know about each other's strengths and weaknesses, the better. And remember something else: in the real world you don't always get assigned to projects with your best buddies. Go get to work. The Universe doesn't care how much people like each other."

The "practical exercise" that Gossage and his staff had prepared did not sound too hard. Rick and Deedee would load a five-hundred-ton ore carrier with low-grade tailings, controlling a semi-smart mining robot to do all the heavy work. They would fly the carrier to CM-2's refinery, drop off the ore, and return to the mine area on the empty carrier. Their own safe return through CM-2's interior would mark the end of the exercise.

But as Deedee remarked, the devil was in the details. Smartness in a mining robot was a mixed blessing, and the instructions given to it must limit its initiative. That meant learning the interaction manual and understanding the robot's powers and limitations. The ore carrier was no better. Exam-

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ining its flight path and fuel needs, Rick and Deedee learned that the fuel supply provided for the round trip was barely enough. One mistake, even a small one, would leave them drifting helplessly away from CM-2 and calling for help from an empty carrier. Turkey Gossage, obviously by intention, had provided no precomputed flight trajectory.

Finally there was a hidden variable mentioned nowhere in the project description: according to training course rumor and legend, Gossage always threw in some extra problem on a practical test, a zinger that could not be predicted ahead of time. You found out about it when it hit you in the face.

Working with Deedee, Rick grudgingly had to admit that she was *smart*. She seemed less cocky and belligerent than he remembered, and she caught on to new ideas at least as fast as he did. He suspected that in a pinch she could read and remember better. And she never seemed to get tired. The cocky statements from Chick Teazle and others of the New Mexico training group, that the East Coasters were all butt-head weirdos, hardly applied to Deedee Mao.

Rick tried to match her. He drove himself harder than ever before, until late at night they found themselves sitting side-by-side and staring helplessly at a set of schematics. The lines on the screen seemed to blur and curve as Rick watched. The circuit had to be completed correctly before the display would advance but nothing seemed to work.

"It *can't* be that hard," Rick muttered at last.

"It isn't." Deedee sighed and reached forward to turn off the display. "It's us. We've saturated. At least, I have. How about you?"

"An hour ago. I just didn't want to admit it." Rick stood and reached up to rub at his stiffened neck muscles. "Better get some sleep. We've got a big day ahead."

"Yeah." Deedee stretched. "I'm in Cabin Twenty-eight. Wanna get it on? Y'know, in free-fall. I hear it's somethin' special."

Her tone of voice was casual and she wasn't looking at Rick. But she was smiling.

He shook his head. "Better with a swamp toad. God. That was us. Only a few weeks ago, and it seems like ten years."

"It *was* ten years. Ten real years." Deedee headed for the exit. "Who said that time proceeds at a uniform rate? Whoever it was, he was crazy."

"Or she was."

"Fair enough. Good night, Rick."

" 'Night, Deedee. Sleep well."

Maybe she did. Rick certainly didn't. He woke long before he needed to, the details of the project swarming through his mind. After half an hour of tossing and turning he rose, dressed, and headed for the cafeteria. It was deserted, as it usually was at such an early hour. He was ordering a meal when Deedee wandered in. Her face was calm but a little pale.

She came straight up to him. "Anything in the rules that says we can't start early?"

"Nothing I know of."

"Right. Let's get going."

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"No." Rick gestured to the place opposite him. "First you eat."

"Hunger sharpens the brain."

"And low blood sugar turns it off." Rick keyed in a huge meal for her, then felt obliged to increase his own order. "We eat. Then we go."

They chewed doggedly, without enjoyment, watching each other's plate until both were empty. By the time they had finished it was close to official breakfast time. Unwilling to talk to other trainees they hurried out and headed for the lock that led to the interior of CM-2.

The hardest thing of all was to avoid rushing. They put their suits on carefully and checked each other's seals. No little surprises there from Turkey Gossage. But as Deedee pointed out, he was not likely to do anything so obvious.

"Which means if he *did* do something obvious," Rick pointed out, "it *would* surprise us. No assumptions."

"Agreed. No assumptions."

They drifted together through the deep interior of CM-2, heading for the side of the planetoid opposite to the main training facilities. The corridor by now seemed as familiar as home. They did not need to consult maps or tracers. The ore carrier and the mining robot, as promised, were waiting in the main loading chamber. The tailings had already been sintered to form oddly-shaped but identical solid blocks, each weighing half a ton. At a pinch, Rick and Deedee could load each one themselves; but that was a sure way to flunk the exercise.

They put the mining robot through its paces on a dummy run, checking that each movement corresponded exactly to that pictured. Finally, and gingerly, Deedee directed the machine to begin loading. She watched the pick-up stage, while Rick counted blocks and monitored their stowing aboard the ore carrier. There were still a hundred more to go when he came out and told Deedee to stop.

"Why? The robot's doing fine."

"Maybe. But we have a problem. The carrier is nearly full. It won't take more than another couple of dozen and we've only loaded nine hundred."

"That can't be right. The carrier is rated for at least five hundred tons cargo mass. Maybe the blocks are heavier than they're supposed to be? Or maybe they're less dense and bigger."

They checked the mass of a sintered block. It was half a ton exactly. Its density was as it should be. Then they crouched in the loading chamber, helmet to helmet, and pored over the electronic and printed manuals. At last Rick sighed. "I get it. I'm a dummy. I should have realized it as soon as the loading started."

Deedee was still staring at the electronic layout diagram of the carrier. "Well, I don't. Everything looks just fine."

"The carrier's fine. The ore blocks are fine, too."

"So what's the problem?"

"It's the *shape* of the blocks. I noticed they looked odd when we first came in. They have the right mass and density but they don't pack tight. There's too much space left between them."

"So what do we do?"

"We look for a better packing

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arrangement, one that fits the blocks together more tightly."

Ten minutes of useless brainstorming was enough to prove that they would never find the answer by abstract thought. Under Deedee's direction the mining robot began to fit blocks one on another, turning them every way to seek the best fit of the irregular faces. The right answer, when they finally reached it, seemed absolutely obvious. With one particular arrangement the sintered blocks keyed in together tightly and seamlessly.

Then the carrier had to be unloaded, and the whole operation begun over. This time the five hundred tons fitted with room to spare. Deedee came over to watch the last block go in. She ordered the mining robot in on top of it before she closed the hatch.

"Think that was the Gossage surprise?" she said as she followed Rick into the ore carrier's control room.

"The first one, maybe. Nobody said he keeps it to one. There could be another right here."

They examined the carrier's status indicators one by one with enormous care, until at last Deedee shrugged. "We can't stay here forever just *looking*. Do it, Luban."

Under Rick's nervous control the carrier crept forward out of the loading chamber and into open space. By all Belt standards the journey was a trivial one: a couple of hundred kilometers through unobstructed vacuum, to rendezvous with another body having negligible velocity relative to CM-2. The training facility's refinery was in an essentially identical orbit around the Earth-Moon system.

That fact did not offer Rick any sense of security. He was keyed tighter than he had ever been until at last the carrier was snugly into the refinery's dock. Then it was Deedee's turn. She unloaded the robot and it carried the sintered ore blocks one by one to the refinery's gigantic hopper.

They stared at each other as the final block went in.

"Smooth," Deedee said at last.

"Too smooth?"

"There's no such thing."

"You know what I mean." Rick stared at the distant bulk of CM-2, its outside lights clearly visible from the refinery. "Let's get back. If there are surprises here I don't want to hang around and wait for them to find us."

He checked the fuel as he switched on the drive. More than enough. He could cut off power after a couple of minutes, coast all the rest of the way to CM-2, and finish with a little fuel to spare. And even with the delay in loading they had plenty of time to complete the assignment before the end of the work period. Maybe the only Gossage surprise was the sintered block shape.

That comforting thought was still in his head when he realized that the star field outside was slowly rotating. Instead of heading straight for CM-2 the ore carrier was yawing, turning its blunt prow farther and farther away from the planned heading.

Rick slapped at the controls and turned all thrust power off.

"What's wrong?" Although he had not said a word, Deedee caught the

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urgency of his movement.

"Drive. We're crabbing." Rick was already calling up onto the control display the rear perspective layout of the carrier, to show the six independent but balanced units that provided the ship's drive. "Something's wrong with one of the modules. We're getting no thrust from it."

Deedee was watching the changing starscape in the front port, noting the exact direction of rotation of the ship. "We're tilting to the right and down." She touched her gloved hand to the display, one finger on the stylized image of a module. "If it's a problem with just one thrustor, it has to be this one. Any of the others would turn us in a different direction."

"Agreed."

"So turn off the *opposite* one of the six, directly across from the bad one. Do it, Rick! That will balance us again."

"I can't." Rick gestured at the control panel. "The thrust modules aren't separately controllable. It's all or nothing."

"So what do we do?"

Rick did not answer. He had called up a section of the ship's manual onto the display. More than anything he had ever wanted in his life, he wanted to read that manual. And he couldn't. The words were too long and unfamiliar, the sentences seemed too complex. He strained to understand, *willing* the words to make sense. And still he couldn't read them. The ship was drifting along, but CM-2 was not directly ahead. Their present course would miss the planetoid.

"Help me, Deedee." Rick was sweating inside his suit. "Help me to figure this out. The manual will tell us what to do. It has to. Help me to read. You read better than me."

"I don't. You know I don't." But Deedee was following Rick's lead, reading each word on the screen aloud, stumbling over the hard ones.

They struggled on, reading in unison, cursing unknown words, correcting each other. Until finally Deedee cried out and pointed at the display, "Att-it-ude. That's what that word is. *Attitude control.* This is the part we want. Come on, Rick. Read it!"

Rick was certainly trying; but he had already discovered that simple need and urgency didn't let you read any faster. They ground on together, word by word, through the next three paragraphs. And at a certain point, groaned in unison.

"It's *obvious!*" Rick slapped his knee with his gloved hand.

"And we're idiots." Deedee repeated the important sentences, gabbling them on the second time through. " 'In the event of thrust module imbalance, the carrier must be returned to the main maintenance facility.'—Yeah. Thanks a lot.—'However, should a thrust module fail and a temporary course adjustment be necessary in space, this can easily be performed by the use of minor lateral control jets. These can be used to spin the ship about its long-it-ud-in-al'—hell of a word—'axis, so that the mean thrust is maintained in the desired direction. The same elementary technique can be used to make general direction adjustments, by halting longitudinal rotation after any suitable angle.' Do it, Rick!"

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"I *am* doing it." Rick was already using the lateral thrustors, turning the ship about its main axis to bring the failed thrustor module onto the opposite side. "I'm going to have to juggle this. If I thrust too long in the other direction we'll swing too far and miss the base on the other side."

"Do it in—little bits." The main thrustors fired, this time in a pattern as jerky as Deedee's speech. "We still have plenty of time. Go easy. You can afford to go easy."

"I will go easy. Trust me."

Rick was eyeing CM-2 as it swung back into view in the forward port. Under his control the drive was stuttering uneasily on and off while the ship rotated unevenly about its main axis. He knew exactly where he wanted to go—into the hard-edged aperture that sat like a bullet-hole in the planetoid's rugged side. But getting there, exactly there, was another matter. It was another half hour before Rick could turn off all power, shiver in released tension, lift his hands from the controls, and wait for the magnetic arrest system to guide the carrier to a berth within CM-2.

Before the grapple was complete Deedee was out of her seat and heading for the lock. "Come on. We have to go."

"What's the hurry?" Rick was moving more slowly, stretching cramped hands as he eased himself from the pilot's chair. "You said we had plenty of time."

"I lied." Deedee was already in the lock, waiting impatiently. "I didn't want you worrying about time when you were flying the carrier. But it's going to be touch and go."

Rick took a glance at his helmet chronometer and leaped for the lock. "We only have twenty-three minutes left!"

"I know." The lock was cycling. "We can do it, though—so long as we don't meet any more snags."

They flew side-by-side from the docking berth to the mine entry point to CM-2. "Say, two minutes each end." Rick hit the entry combination. "Twelve minutes to get through the tunnels—that's about as fast as we can go. But we still have a seven minute cushion." He keyed in the entry combination again. "What's wrong with this thing? It shouldn't take this long."

"The power has been turned off." Deedee pointed to the telltale set in the great door. "And it's too heavy for manual operation."

"Turkey. The bastard. He's screwed us. We can't get in."

"Then we'll have to go around. Or use one of the side tunnels?"

"No good. They all lead outside, not to the training facility."

"That's our answer." Deedee had turned. "We can go right around the outside. Don't waste time with that door, Rick. *Come on!* We're down to twenty-one minutes."

She led the way, zooming at maximum suit speed for the open entrance of the mine loading chamber. Rick, close behind, did the calculation. They had to make their way right around CM-2 to almost the opposite side of the planetoid. Say, three kilometers. If they could average ten per hour, they would do it. If not. . . .

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All Rick could think of was that early this morning he had made Deedee sit down and eat breakfast when she was hyped up and raring to go. If they were too late now, it was his fault.

They came to the edge of the loading chamber and burst out from the darkness. As Deedee, still ahead of Rick, emerged into full sunlight she reversed suit jets and came to an abrupt dead halt.

"Keep going, Dee. I'm right behind you."

But she was not moving. "Listen to your dosimeter, Rick."

He became aware of a tinny rattle in the background. It was his suit's radiation monitor, operating well above the danger level.

"Back inside." And when he hesitated, "We have to, Rick. *Right now.*" She had him by the arm of his suit, towing him. "It must be a solar burst, a sudden one and a big one. We're safe enough as soon as we get some rock shielding around us."

They were already out of sight of the Sun. Safe enough. And *failed.* Rick glanced at his chronometer. Eighteen and a half minutes.

"Deedee, we wouldn't be outside for very long. I'll bet the integrated dose would be small enough, it wouldn't harm us."

"Maybe. But are you *sure?*"

He wasn't. Worse than that, he didn't know how to make sure. The calculation couldn't be very difficult, no more than a formula and a few simple summations. Jigger would probably have done it in his head. But Rick didn't know how to do it at all. He groaned.

"We're safe enough here." Deedee had misunderstood the reason for his misery. "Rock is a perfect shield."

"I know. I don't want a shield. I want to beat that goddamn deadline."

"We can't possibly. A solar storm could last for days, and we have only seventeen minutes left."

Rock is a perfect shield.

"Dee, we still have a chance. The Sun is shining almost directly into the loading chamber. The training facility is on the opposite side. We can go through a side tunnel to a point where we're out of direct sunlight, then jet the rest of the way outside shielded by CM-2 itself."

"Sixteen minutes. We'll never do it in time." But she was following Rick as he plunged back into the dark interior. He picked one side tunnel and went into it without hesitating. Fortunately Deedee didn't ask why Rick knew so well the network of passages and chambers that crisscrossed the interior of CM-2. He certainly wasn't going to mention it or the disastrous episode it had led to with Gina.

The passageways had been designed for mining rather than rapid travel through them. The trip through the interior seemed to take forever. At last Rick and Deedee were at the surface again, about a quarter of the way around the planetoid, but they were running out of time. Five minutes left. A kilometer and a half to go on the outside, hugging close to CM-2 to avoid the solar flare. It didn't sound far. But it meant averaging eighteen kilometers an hour. You couldn't do that. Not in a suit, zooming around the irregular exterior of a planetoid.

Rick knew it. Deedee probably

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knew it, too. Neither said a word as the final minute flashed past and the deadline was missed. They kept going, bitterly, all the way to the lock that would lead them into the training facility.

As the lock opened, Rick halted. "No good. Six minutes late. Sorry."

"I know." Deedee came to his side, put an arm around him, and hugged him. She leaned her helmet against his as they moved into the lock together. "We gave it our best shot. Nobody can take that away from us."

The lock pressure equalized. They reached up to remove their helmets as the inner door opened—and found themselves staring at the anxious face of Turkey Gossage. Turkey glanced at once at his watch.

"Don't say it." Rick moved out of the lock. "Six minutes late."

"I wasn't going to. Did you come around the outside?"

"Part of the way." Deedee came to stand at Rick's side.

"Let me see your dosimeters so—"

"No problem. We did the first part in the interior, and we only came outside when CM-2 was shielding us from the Sun."

"Smart move." Gossage relaxed visibly. "Of course, even in the Sun the dose you'd have received in the short time you were there would have been tolerable."

"We weren't sure." Rick was suddenly more tired than he had ever been. "We didn't know how to calculate it."

"I can show you that in five minutes."

"I'm sure you can. But not today, sir, if you don't mind." Rick slumped against the chamber wall and allowed his arms and legs to go limp. "We did our best, we really did."

"And we came so close." Deedee flopped down by Rick's side. "If there had been one less problem to solve—just one."

"I see. Would you agree with that, Luban?" Turkey seemed more amused than sympathetic.

"Yes. But I don't see why it matters."

"It matters very much. To me, at least." Gossage squatted down so that he was facing the two of them. "You see, it's not every day that people mistake me for a deity." And, when Rick and Deedee stared at him with dull and exhausted eyes, "I gave you a test that I thought would stretch you right to your limits. If you did everything right, and fast, and clean, you could make it back before the deadline—just. I rigged the shape of the sintered blocks. I fixed the drive so it would go wonky on the return trip. I turned off the power on the main entry door so you couldn't get back inside and would have to come around the outside. But if there's one thing that even Turkey Gossage can't do, it's to arrange a solar flare for his special convenience. I'd have to be God Almighty to do that. The flare wasn't in my plans, any more than it was in yours."

He reached out, taking Deedee and Rick's right hands in his. "If it hadn't been for the flare you'd have beaten your deadline with time to spare. That's good enough for me. You did well, better than I expected. You've

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passed. Now, don't go to sleep on me!"

Rick and Deedee had simultaneously closed their eyes. They showed no sign of opening them again.

"All right." Gossage stood up. He was still holding their hands and his movement lifted them to their feet. "You've passed the practical test, the pair of you, but you don't seem to care. Eat and rest, rest and eat. We'll talk later." He released them, turned, and headed for the tunnel. As he reached it he added, without turning his head, "Just don't get cocky. You still have theory finals—and I guarantee they'll be tough. You won't have things this nice and easy all the time."

CHAPTER TEN

Turkey Gossage was as good as his word and better. The theory final was more than tough. It was murderous. Rick staggered out of a private cubicle—no chance to "borrow" your answers on CM-2—and saw his own despair mirrored on everyone's face. They had been asked questions far beyond anything taught in class. Jigger Tait's early warning had been right: if you didn't learn how to browse all around a subject, you were in trouble at Vanguard Mining.

Give the formula for the velocity, v, *achieved by a ship accelerating with acceleration* a *for a time* t.

That was fair. Turkey had pounded the simple formula, $v = at$, into their heads a dozen times. He said they had to remember it for the rest of their lives.

But then came the zinger: *State circumstances when the formula that you have just given does not apply.*

That had definitely *not* been mentioned anywhere, in any lesson. Rick had a vague feeling that things went wrong if you kept on accelerating until the calculated velocity was near the speed of light. He knew for sure that the formula couldn't work if the answer you got was *more* than the speed of light, because nothing could go faster than that. But he had absolutely no idea what the right relation between speed and acceleration would be in such a case.

Stating all those thoughts, clearly and precisely, was just about impossible. Rick decided that he had waffled. Whoever listened to his spoken answer would know it. It all came back to what Mr. Hamel had said on the far-off day Rick had been kicked out of school: it's a lot easier to be exact when you *write* something than if you try to *speak* it.

The good news was that the tests were finally over. The one he had just taken was the last. Now came the wait to learn how badly he had done. Turkey Gossage knew they would all be in agony until the final results were tallied. He had promised not to keep them hanging longer than one day.

What Turkey could not guarantee was the subjective length of twenty-four hours. As Deedee had said, time didn't proceed at a uniform rate. When you were having fun, it flew by. When you were waiting for something, every minute dragged.

Like now.

The exam had finished at midday. Afternoon had been occupied in chores just tricky enough to keep a person from brooding over other

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things. The make-work tasks were all done by dinnertime, and no activities had been set for later. Some instinct for solitude took over. The usual evening group session in the cafeteria, where people met to talk about the events of the day, never happened. Tonight everyone quietly picked up cartons of carry-out food and left at once.

Rick sought out his own private place, an abandoned outer chamber of CM-2 where he could sit and watch the stately rotation of the starfield. He was not sure he could stand the idea of going back to the dorm at all until tomorrow morning.

The asteroid training station made one revolution every twenty minutes, too slow to notice unless you were looking outside. As Rick was eating he idly took his drinking straw and released it. The straw drifted steadily downward, to land on the glassy floor of the observation room. There should be a way to calculate the effective gravity in which the straw fell, using the size of CM-2 and the time it took for the planetoid to turn on its axis. Jigger Tait or Gina Styan would rattle off a formula, but Rick did not know it.

The steady turn of the station was bringing Earth into view on the left. He watched it mindlessly, all the way until it slowly vanished from sight on the right. Then he realized that his mind had not been blank at all. He was thinking again about that damned theory exam, mentally reviewing his answers—and revising them, even though there was no way to change anything! It was a sure way to go crazy.

Rick left the observation room. He went wandering around the exterior paths of CM-2, until he came to the radiation-proof chamber where he had once tried to jump Gina Styan. He paused outside the door. He might have flunked the training course, but he'd learned at least one thing since he came to Vanguard Mining. He felt his testicles draw upward in his scrotum, his body's reminder of the agony he had felt when Gina showed who was really the boss. It would be a long time before he tried anything like that again.

The door to the shielded chamber was open. Someone was sitting inside with the lights off. Apparently Rick was not the only one who didn't want company. He was all set to retreat when a voice said, "Come on in. I felt sure you were heading this way. Don't put the light on if you don't want to."

To Rick's astonishment he knew that voice. It was Turkey Gossage. Rick peered into the dark interior.

"You knew where I was?"

"Of course. Many's the night I've done the same thing myself. There's no better place than the outer ring observation ports to feel the size and majesty of the Universe, and know there's more in it than you'll ever see or understand. And I knew just when you left there."

"You've been watching me?"

"Not just you. Everybody." Turkey gestured to Rick to come in and raised the level of the lights. "We learned the hard way not to let any trainee go off alone and unmonitored the night after finals. Sit down and take it easy. Are you feeling upset?"

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"I don't know if that's the right word. I can't stop thinking about the exam."

"I'm sure. That's why I'm here—to end the suspense." Turkey thrust out his hand. He had a big grin on his face. "It's over, Luban. Congratulations. You passed the final. You'll be heading on to the next stage of training."

Rick gaped at him. "Passed? But you said that *tomorrow*—"

"That was my time cushion, a margin for error. We finished the final comparison and collating of results four hours ago. I've been doing the rounds since, telling people. You're the last."

Rick finally did as Turkey had suggested, and flopped down onto the padded floor. *He had passed!* He would be leaving CM-2 and going out to the Belt. But it had come so soon and so suddenly—it did not feel real.

"When? When will I go?"

"Soon. A day or two."

"So—what happens now?"

"You mean, right this minute? Well, I don't imagine you feel much like sleeping."

"Never!"

"Good. There's a celebration party in the senior mess, and it should be swinging along nicely by now. So I suggest you head over there."

"Are you coming, too?"

"Eventually. But not for a while." Turkey's voice became heavier and all the humor went out of it. "You see, Luban, this training station isn't Happy House. It's not like your school back on Earth, where everybody has to do well and everyone must graduate with honors, otherwise their precious self-esteem would be ruined. Nearly a fourth of the people on the training course have failed. They won't be going to any party, and they need me tonight a lot more than you do. So maybe I'll see you later. But if not—you'll understand why."

"Who—who failed?" And, when Gossage did not answer, "Vido Valdez, and Deedee Mao, and—"

"I prefer not to talk about individuals. Why don't you get along to the party? There's a complete list posted there." Turkey nodded. "Go now."

It was an order, in a tone of voice that the trainees had learned not to argue with. Turkey would accept no more questions. Rick swallowed, rose to his feet, and stumbled out.

His path to the senior mess, normally off-limits to lowly trainees, took him past the dormitories. All the lights were on in spite of the late hour, but the corridors and rooms were eerily deserted, like a ghost of their usual selves. Rick hurried past his own dorm and the open doors of the next two along. He glanced inside each, not expecting anyone, and was surprised to see a heavy-set form at the far end of the second dorm, sitting on a bunk with his back to the door.

It was Vido. Rick paused. The two of them had hardly spoken a word since their last fight. He should go on. But the other's hunched shoulders spoke of total misery.

Rick moved forward hesitantly to Vido's side. "I'm really sorry," he began, then could add nothing more.

Vido turned to stare up at him, his broad black face stony with grief. "It was my fault. All my fault."

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Rick reached out his hand intending to pat Vido's shoulder, then drew it back. "You did your best. We all did. I'm really sorry that you—that it didn't work out for you." He could not bring himself to say that awful word, *failed.*

"For me?" Vido stared in confusion.

"That you didn't pass."

"But I did! You thought—"

"But you said—"

"Not me. *Monkey!* She failed, and it was all my fault." Vido put his head down and stared at nothing. "She came to you for help, an' I hated it. I asked her not to do that no more. And she didn't, for my sake. But you could have helped her. It was the math, you see, she could handle the rest of it but she couldn't handle that. An' you're a real good math teacher, Alice an' Deedee both say so. If only I'd been less selfish, if only I just hadn't *stopped* her."

Rick hesitated again. He wasn't sure what he wanted to say next would please Vido, but he knew that he had to say it. "Vido, it wasn't you. I talked to Monkey for a long time that day before you came along. When it comes to math, she just doesn't get it. Not at all. I could have taught her every day, so could you, and it wouldn't have made any difference. She'd never have passed that theory final in a hundred years. She just didn't seem able to get the basic ideas. You know her a lot better than me. Surely you saw that?"

"I thought it was me. I thought I wasn't explaining right."

"It wasn't you. It was Monkey. I'm really sorry, Vido." Rick finally reached out and patted the other's shoulder, knowing it was something that no sixteen-year-old male did to another male in his old school without risking mockery. But the hell with that, things were different in space. "I'm really glad you passed. Honest. Congratulations."

Vido looked startled. "I never asked. You?—"

"I passed, too. We'll both be going to the Belt."

"Yeah. Guess so. The Belt." Vido took a deep breath, then stood up and held out his hand. "Congratulations. But you're not at the party!"

"I'm on my way. You should go, too. It's terrible about Monkey, but there's nothing you can do about it. Let's go."

"I won't be able to enjoy the party without her. Shit, I'll probably take a swipe at Gossage the minute I see him, for flunking her."

"I don't think so. He won't be there." Rick repeated what Turkey had told him. "He's got the toughest job of all tonight. You owe it to him to go and at least try to have a good time."

"Yeah. Maybe I do." Vido sighed. "To hell with it. To hell with everything. I thought this was goin' to be the best day of my life, or it was goin' to be the worst. An' here it is both."

He sniffed and rubbed his eyes. For a change, both of them were bloodshot. "Let's go, Luban. Before people start sayin' I'm getting soft."

For the rest of the way, Rick wondered about Deedee Mao. He knew she was really smart, but she might not be good at taking tests. Suppose that she, like Monkey, had flunked? It was a huge relief to enter the crowd-

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ed senior mess, and see her almost at once. She had been watching the door with an anxious expression, and the moment she saw him come in her face lit up and she gave him a double thumbs-up sign from across the room.

She came pushing across to his side. "I'd really started to wonder about you." She had to put her face close to his and shout because of the noise.

"Hell, Deedee, if somebody like *you* could pass, I—ouch!" Rick grunted as she poked him in the ribs. "What's going on over there? I thought this was supposed to be a party."

A line of trainees was forming at the other side of the room, facing Jigger Tait.

"Not just a party. This is graduation. First you graduate, *then* you party."

"You did?"

"Graduate? No. I was waiting for you."

"And that's it? The whole thing?" Rick had dreaded and half-expected the pomp and circumstance of a high school graduation ceremony, with robes and pictures and diplomas and celebrities, and boring windbag speeches *ad nauseam.* What people seemed to be getting was one quick handshake from an overall-clad Jigger Tait, "standing in for Turkey Gossage the one and only," as he put it.

"What about my certificate?" Chick Teazle called out from halfway along the line.

"What would you do with a certificate if you had one?" Jigger was beaming. "You can't hang it on the wall where you're going—none of you will have a wall. You'll be lucky if you get food and air."

"We'd treasure your signature, sir." Gladys de Witt was still wearing a cast and performed a southpaw handshake with Jigger. A sprung cable had broken her right arm on the final stage of her practical test, but she had finished, flying the ship home to base one-handed. Now she waved her white cast in the air. "You can sign this for me instead."

Jigger did so, to enormous applause. The ones closest to them hooted at what he had written, while Gladys turned pink and held her arm against her body.

The line moved along slowly. Deedee and Rick were at the very end. "Thank God!" Jigger said, when they finally reached him. "How do politicians stand it? The only good bit must be kissing babies—once they reach the right age." He bent over and gave Deedee a hug and kiss instead of a handshake, producing cries of "No fair!" and "Do one, you do us all!" from the other girls who saw it happen.

"You can come and see me in private," Jigger called back. "That's my quota for tonight." He winked at Rick, the last in the line. "Not a word to Gina, all right? She'll be here a bit later, she can't resist a dance."

Music was beginning, loud and with a foot-tapping bass. A few couples came out to move awkwardly in time to it. Walking and running in low gravity was something that they had all practiced. Dancing was another matter. It was the first time that most trainees had tried it on CM-2. Rick,

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standing at the edge of the area cleared for dancing, was in even worse shape. He and his friends at school had always sneered at dancing and he had no idea how to do it.

He stared around the room. He had not seen the list that Turkey had mentioned, but he didn't need it. He knew every trainee by name.

Vido, of course, had made it. Rick wondered if the two of them had again achieved near-identical scores. There was Chick Teazle, no surprise, and Gladys and Deedee next to him. At the edge of the dance floor, standing by herself and staring blank-eyed at the dancers, was Alice Klein. Rick was not surprised by that, either. In spite of her troubles with math, Alice had a way of scraping through. So did Goggles Landau, standing next to her. He wasn't wearing glasses and he must have taken out his contacts, because he was squinting his eyes at everyone, probably wondering who they were.

So who was missing? Monkey, of course. So far as Vido was concerned she was the only one who mattered. Who else? There was no sign of Cokie Mulligan. He had sworn at the beginning that he was done with school forever, and now it looked like he was right. Rick also couldn't see Henrik Voelker, the "Carolina Kid" that the other East Coasters all swore was a mad genius. He had probably aced the hardest theory questions, but screwed up totally on anything that needed a bit of common sense. A handful of others had been no-hopers after their failed efforts on the practical test. They had been given a chance to make it up somehow on the theory, but apparently none of them had.

All the same, it looked like the class as a whole had beaten the odds. From a total of forty trainees starting out, thirty or so were here in the room. Rick started to count. He had reached seventeen when he became aware of Jigger Tait at his side.

"Not dancing?"

Rick shook his head. "Not yet. I was just counting how many of us there are left."

"You'll have plenty of time for that on the way out to the Belt. You shouldn't do it now. You've done enough work for one day, and you ought to make the most of tonight. Tomorrow the honeymoon's over. No more spoon-feeding. Things get tough, and you learn what *real* work is like. Come on."

He grabbed Rick by the arm and led him, puzzled, around the dance floor. They were heading for the place from which Gladys de Witt had now vanished, leaving Deedee standing alone.

"After the first dance you're on your own. For this one you get no choice." Jigger beckoned Deedee onto the floor, faced her and Rick toward each other, and walked briskly away.

There was a long, awkward moment. Finally Deedee shrugged, stuck her tongue out after Jigger, and began to move her shoulders and arms in time to the music. "You hear what the man said."

"I'm a lousy dancer." An understatement if ever there was one.

"So what? You're not here for prizes." And, when Rick still stood

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rooted to the spot, "Look, Luban, I know you got no more rhythm than a fire hydrant. You want *everybody* to know that as well as me? Watch what I do, and move them big feet."

They were standing out on the dance floor. He would be even more conspicuous not dancing than dancing badly. Rick began to move, trying to follow what Deedee was doing. After the first minute he realized that no one but Deedee would notice whatever dumb moves he made. They were all too wrapped up in their own efforts.

He began to relax. Deedee was grinning at him, yet he knew she wasn't grinning at *him.* She was just enjoying herself. And she could dance like a professional. Rick tried to mimic that supple, limber action. He knew he was failing, but she didn't seem to mind.

Tomorrow the honeymoon's over. No more spoon-feeding. Things get tough, and you learn what real work is like.

What was it going to be like, out there in the Belt? That thought flashed into Rick's mind, and was followed at once by the sudden memory of an answer he had given on the theory test. It was the wrong answer, and now he knew the right one. But—*it didn't matter.*

He smiled at Deedee, and was rewarded by a flash of white teeth and a graceful sexy pirouette that was offered for him alone.

He caught her as she finished the turn and moved her body against him. She put her mouth to his ear and whispered, "Hey! That's more like it."

Unbelievably, the tests were over. They had passed, and Jigger Tait was right. They had done enough work for one day. For tonight at least they had earned some fun. ■

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NASA HONORS CLARKE

By G. Harry Stine

The National Aeronautics and Space Administration has again honored one of our own with the NASA Distinguished Public Service Medal, the highest award that can be given to any non-NASA person. (Robert A. Heinlein was posthumously awarded this medal on October 6, 1988.) Speaking in front of a full-scale replica of the *Galileo* space probe at the Jet Propulsion Laboratory in Pasadena, California on August 18, 1995, NASA Administrator Daniel C. Goldin made the presentation to Arthur C. Clarke in Sri Lanka in an appropriate manner: via television using communications satellites in geosynchronous orbit.

Gathered for the occasion in JPL's von Karman Auditorium was a bevy of Clarke's SF author colleagues—Dr. Arlan Andrews, Karen and Poul Anderson, Dr. Yoji Kondo, Dr. Larry Niven, Dr. Jerry Pournelle, G. Harry Stine, and Dr. Harry Turtledove.

Dan Goldin turned out to be a reader of this magazine and of SF in general, perhaps the first NASA Administrator to admit this. In his remarks, Goldin said, "It's a privilege to be hooked up with you electronically. We're doing it through an idea that came out of your most productive and fertile mind fifty years ago . . . opening the space frontier takes engineers. It takes scientists. And it takes visionaries and dreamers like you. I've read all your works. They inspired me and most of the people I talk to in the space program. So you are part of us. You're an Honorary Member of NASA. You are the fuel that helps us go. We need dreamers because dreamers are able to communicate to the people of this planet. . . . We're here to celebrate your great works and the impact you have had on the exploration program . . . Jerry Pournelle helped us gather science fiction writers in Pasadena to share this. We want to celebrate what you've done for the world and for the space program by bestowing upon you the NASA Distinguished Public Service Medal."

Goldin then read the citation: "To Arthur Charles Clarke for his continuing contributions over more than half a century to the exploration and development of space. No writer, living or dead, has done more to demonstrate to the general public the practical value and the future potential of continued space exploration."

In a surprise announcement, Goldin revealed that when the *Sojourner* lander sets down on Mars in 1996, it will carry a CD-ROM on which, among other things, will be the text of Bradbury's *Martian Chronicles* as well as Clarke's *The Transit of Earth* and *The Sands of Mars.*

The presentation was part of a worldwide satellite television tribute to Clarke sponsored by the British Interplanetary Society. It involved satellite feeds from London, IntelSat in Washington, JPL in Pasadena, and Clarke's own ground station in Sri Lanka.

What an appropriate way to honor Arthur!

Afterwards, we SF authors present had lunch with Goldin because no author would turn down a free lunch. Sorry you couldn't be there in person, Arthur!

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Testament, Valerie J. Freireich, ROC, $5.99, 317 pp. (ISBN: 0451-45459-6).
Harvest the Fire, Poul Anderson, TOR, $5.99, 190 pp. (ISBN: 0-312-85943-0).
Quasar, Jamil Nasir, Bantam, $5.99, 210 pp. (ISBN:0-553-56886-8).
Project Farcry, Pauline Ashwell, TOR, $23.95, 384 pp. (ISBN: 0-312-85861-2).
Stepwater, L. Warren Douglas, ROC, $4.99, 288 pp. (ISBN: 0-451-45468-5).
Buck Rogers, Martin Caidin, TSR, $19.95, 347 + viii pp. (ISBN: 0-7869-0144-6).

In Valerie J. Freireich's last novel, *Becoming Human,* she introduced us to the Polite Harmony of Worlds, a far-future interstellar civilization whose guiding philosophy is Jonism—an anti-religious, anti-superstitious doctrine that stresses rationality and order above all, and despite its "rationality" is able to define humans who have been modified by genetic engineering as "Altereds," subhuman and defective and unworthy of inclusion in the Jonist civilization. That is, says Freireich, people may call themselves rational, but bigotry is pretty basic stuff—people just have to have somebody to hate.

If you have a taste for such cognitive dissonance, Freireich has another serving for you. It's **Testament**, set in that same future but on a different world, Testament, whose inhabitants were Altered in such a way that mothers pass their memories to their children, embedded in mitochondrial DNA. This alteration was designed a thousand years before, on Earth, to permit interstellar colonists to retain a memory of their home world, to give them some immunity to loss of books and other records. It has served them well, leading inevitably to a society dominated by women, though the random vagaries of genetics do toss up "singletons" such as Gray Bridger, who has not received his ancestral memories. Naturally enough, he feels estranged; he wants to leave, to go out among the Harmony's worlds and be surrounded by others whose memories are just like his own.

Unfortunately, the Harmony is ruled by men. Perhaps it's just their basic Jonist bigotry. Perhaps they fear that an Alteration associated with female dominance is just too threatening. Whatever, they have erected barriers. Men may leave only if they are single and symptomatically normal. Women may leave only if they are sterile. And the Harmony has set in place a governor whose bigotry is extreme even in the Harmony; he would like nothing better than to exterminate the Testamenters.

Gray Bridger applies to leave. He

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passes the tests. But then the record search turns up a wife he has never met. He storms home and discovers the wife, Dancer, is an "alia," as much a mutant as he, whose mind has been swamped by the chaotically competing memories of her ancestors. When a drug is used to stabilize a single personality, she becomes Janet Bridger, founder of the Bridger Line on Earth, and she remembers an affair with the founder of Jonism, Jon Hsu.

Or does she? There is a hint that Hsu was simply an acronym for the Hard Science Underground, which at the time was resisting social controls—arisen from rampant superstition and religious fanaticism—on scientific research. Perhaps "Jon Hsu" was a pseudonym. Perhaps . . .

Does it matter? To the Jonists it does, for here on Testament is Ahman Martin Penn, once an aide to Elector Jeroen Lee, whose revelation in *Becoming Human* as an Altered (Gasp!) has brought the debate over the status of these "subhuman monsters" to the fore. He is basically just keeping his head down, so his career won't be damaged by association with Lee, but he is also seeking an answer to the question of whether Jonism is missing something important in its surpassing reliance on rationality. Is there Mystery? Is there a god? Was there a baby in the bathwater Jonism pitched out the window? And when he hires Gray Bridger as his guide, things begin to roll.

The Bridger clan's "precasters," elder women who recall their ancestors all the way back to Janet Bridger and have the talent to use that wealth of background to analyze events and project the future, apparently have plans for Gray. Led by his grandmother, they have saddled him with a wife to keep him home. Or is there a plot to get a fertile woman offplanet? Or . . . ?

Janet's memories of Jon Hsu come to Penn's attention. He sees immediately that they call into question certain basics of Jonism; they must be taken to the Harmony for careful analysis and appraisal, for they may have a great deal to do with redefining Altereds as human and thereby saving Jeroen Lee. The bigoted governor sees only a threat to his most cherished beliefs and declares that the memories—whether true or not—must be extinguished.

Freireich's hand is sure as she juggles a series of convincing characters (only the governor is thin, too villainous a villain to believe) and layers of misdirection (is there a precaster plot against the Harmony? Is it a matter of getting Gray offworld, or Dancer, or his sister Mead, who is sleeping with Penn? Or is it a matter of memories, of ideas?). There is immense momentum, and at the end a truly crashing finale and an opening out upon the Universe.

This one has that rare combination of scope and depth. You'll love it.

In *Harvest of Stars* and *The Stars Are Also Fire,* Poul Anderson leaped humanity into space, led by Anson Guthrie and his Fireball Enterprises despite the efforts of a timid centrist tyranny to rein him in. As a download, Guthrie wound up leading the settlement of Demeter, a world of Alpha

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Centauri. Later the gengineered Lunarians hied off to settle Proserpina, a comet in the Kuiper Belt. Gengineered monk seals and human allies formed a new society in Earth's seas. And the rest of humanity accepted the rule of the artificial intelligences that were quickly becoming a global mind, the cybercosm or Teramind.

With **Harvest the Fire**, Anderson assures us that there will always remain discontent. Meet Jesse Nichol, a would-be poet who is sure that in a less placid society he could be creative, productive, and famous. He is given to savage moods that ruin all his relationships with others, notably with women, until he moves to the Moon in search of whatever remains of frontier excitement. There he becomes one of the very few human space pilots and gains a Lunarian lover, Falaire, who seems able to tolerate his moods.

It doesn't take long for Jesse to realize that Falaire is part of the Moon's revolutionary underground, nor to be invited to meet with a visitor from Proserpina. There is, of course, a plot awaiting him, a role only he can play, perhaps even a justice he can serve, giving the Proserpinans an independence Earth's Teramind refuses them. He is ripe for the plucking, just as have been many poets of the past, but Falaire and her friends overplay their hand with drama and blackmail. He cooperates, but when he discovers the agent of the Teramind hidden in a cupboard and learns the truth of their scheming. . . .

Does he betray them? He has the chance, he has the savage reaction one might expect of the love-betrayed, he ponders it. But he is a would-be poet, and before him looms Romance. Does he? I'll leave it to you to learn his answer.

For now, I'll simply say that this one strikes me as Anderson in a minor key. The book is quite short, a novella dressed up with 24 pieces of artwork by Vincent Di Fate, and its tone is self-consciously "artistic."

In Jamil Nasir's first novel, **Quasar**, humanity has been reduced to the population of a single city ruled by powerful, wealthy families. The rest of the world is dead, its ecosystems destroyed by biocidal wars; it will not be inhabitable again for decades or more. A space program searches desperately for some alternative to Earth. And in the city, the authorities search out mutants and banish them to the sewers and catacombs far beneath the realm of light.

Meet Theodore Karmade, a fairly ordinary psychiatric technician. He has just been hired by the Zant family, richest and most powerful of the city's rulers, to rescue Quasar Zant, orphaned heiress to two ex-astronauts famous for their inventions and flaming fruitcake, from the grip of a brain-stimulation device. To break her free, he must promise her the illegal trip she has been demanding to Death Hole Warren, where the worst of the mutants live.

He succeeds and is sent home with ample payment. But then Quasar shows up, insisting that he follow through on that promise. He accompanies her to the Warren's verge be-

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fore finding a chance to haul her back, and then the Zant family's goons grab them both. He soon learns that Quasar's guardian is even crazier than she and lusts for wealth and power. The reader wonders if Quasar's insanity is not drug-induced; soon, however, Nasir reveals that it was apparently induced by loving parents.

Why? That is something of a mystery. I can say that it has something to do with the crash of Quasar's parents' spaceship into a rock, with the giant eyeballs Karmade glimpses from time to time, and with the inhabitants—refugees—deep in Death Hole Warren. The story's trappings are modern—plenty of psychological and psychiatric jargon, psychoactive medications, holograms, and brain-computer interfaces—and Nasir keeps the plot moving very nicely. This is a nice fast read, very entertaining, worth its paperback price. On the other hand, its overall flavor is a bit antique, smelling of 1930-ish tales of super-science and super-villainy and intervening aliens and lacking much in the way of deeper point. If you prefer tales that feel modern in more than their furniture, you won't care for this one.

Pauline Ashwell's first novel, *Unwillingly to Earth,* was assembled from pieces that had appeared in this magazine over a thirty year period—1958 to 1988. When I reviewed it in the December 1992 column, I noted that at least its older segments smelled strongly of their prefeminist times.

Her second novel, **Project Farcry**, has roots just as old, though they are not recognized on the copyright page. Its opening segment, "Big Sword," also appeared here in 1958, under her "Paul Ash" pseudonym. And it's worth noting that this story survives rather better; it feels a bit like the Heinlein juveniles (whose appeal was *never* restricted to kids) or perhaps more like the Andre Norton books, for she did love to combine kids and telepathic critters.

The tale opens on the world of Lambda, where human scientists are studying everything in sight. They're not paying any attention to the intelligent natives because they do not know they are there—they are few, small, and inconspicuous, and they look like insects—but the natives are watching them. Indeed, they have taken advantage of a trick of their biology to produce a larger and brainier than usual individual, Big Sword, so named for the thorn he carries in his leg-pouch. As a telepath, he is aware that the humans think, though their thoughts seem to stop when they open their mouths.

The leader of the humans is John Jordan, who has brought with him on this expedition his son Ricky. Ricky, you see, was in trouble with his mother and her latest husband, as well as everyone else around, because he was a snoop. At least, he always seemed to know things he could only have learned by eavesdropping, steaming open letters, and rummaging through private files. And now he's getting into the same sort of trouble on Lambda.

I'm sure you can see where this is leading. Since 1958, the situation has become pretty familiar. Of course the kid's a telepath, and of course he makes contact with Big Sword, and of

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course he convinces the grown-ups there are intelligent bugs that hatch from plant pods and live by photosynthesis, after which the grown-ups solve a problem that is threatening the Lambdans with extinction. They then swear to keep the Lambdans's existence secret.

It's a nice feel-good tale, and quite complete by itself, at least until you ask what happened to Ricky later. And that's the rest of the book. At the age of seventeen, he is on a voyage testing a matter transmitter that goes wrong, closing off an entire world, Planet C, behind an impenetrable barrier. Later, he shows up on Earth, looking for a way to make telepathy useful. He plays a role in solving a police mystery and makes friends with Sebastian Karel, who turns out to be another telepath. He manages to prove that telepathy can be used for faster-than-light communications and becomes the head of the Space Force department in charge of "Communications (Long-Distance)." In due time, he returns to Lambda to seek the Lambdans's aid in breaking the barrier around Planet C.

Ashwell pays nice attention to detail, bringing aliens, humans, and their worlds quite adequately to life. Her plot is full enough of incident to keep it interesting, even though the basic scheme is very simple indeed—kid turns problem into talent and makes good. And there are no warped psychologies, no graphic violence, and no sex, so the novel is just as suitable for kids as anything by Heinlein or Norton ever was.

L. Warren Douglas has created an intriguing future for his new series. He posits that we will pass through a period when corporations will use genetic engineering to exploit people quite dreadfully—adding the genes of bears to humans, for instance, so that workers will hibernate during the off season and the corporations won't have to feed them. The result will be seven variants of the familiar old-human line of humanity—bearlike bors, elfin wends, otterish mantees, nomadic fards, sulfurous tarbeks, polar ikuts. Each is adapted to a particular environment—bors to mountain caves, fards to deserts, mantees to water.

Despite tremendous physical differences, the variants are capable of mating with each other. Since hybrid offspring revert to the old-human form, there is a powerful tendency to look down on the old-human type as an impure, corrupted consequence of unnatural perversion. Yet at the same time, because those long-gone genetic engineers wanted to bind old-humans and their creations close together, each variant responds more strongly to the old-human sexual pheromones than to its own, and old-humans turn on to the variants, too.

Millennia later, humans of all kinds are spread among the stars. The thousands of worlds of the Xarafeille Stream are overseen by the old-human Arbiter, John Minder XXIII. He does not rule; he keeps the peace by manipulation and negotiation; only when that fails may he call upon a hidden space fleet and planets full of old-style warriors; awareness of that possibility helps him in his quieter maneuverings. That is, like Teddy Roosevelt, he

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speaks softly and carries a big stick; the United Nations and NATO have surely convinced us in recent years that speaking loudly and carrying a swizzle stick do not work very well.

However, in order to grasp his particular big stick, he needs seven data blocks full of Arbiter history. Alas, when his father died and he assumed the Arbiter's mantle, the data blocks proved to be missing, snaffled by his archeologist elder brother. Now both brother and data blocks have vanished. And if the word gets out that he has nothing to back his Arbiting, the worlds of humanity must surely descend into chaos. No wonder that generations of Minders have kept as a seat an ancient barrel—a genuine powder keg!

Fortunately, there are copies of the data blocks. They are scattered on several worlds, squirreled away where no one may suspect what they are. If he can just lay hands on them. . . .

Douglas promises us not a trilogy (though ROC has contracted only for that many), but a seven-book series, and then no more. The first is **Stepwater**, in which bors and mantees nearly start a war. The tale begins when Barq, heir to the bors domain of Margal Steep, beds Girelf, heiress to the local mantee throng, which resides in the river that runs beneath the hollowed-out mountain that is Margal Steep and has the rights to the shore for about a mile from the water's edge. This is disaster, for a bors imprints upon his first mate, and when Barq imprints upon Girelf, he ruins his future—or so he and all his kin believe. Threatened with a brainscrubbing to straighten out his imprinting, he flees and becomes a notorious pervert, not only bedding females of every variant on Stepwater (including—Gasp!—old-humans), but setting up a line of very successful and lucrative brothels.

Meanwhile, back at Margal Steep, the mantees are building their dam higher and higher. The water is rising, the shoreline pushing outward, the lower tunnels of the bors home flooding, the walls and ceilings crumbling. Indeed, the day comes when the ceiling caves in on the present rulers, and Barq, pervert or no, willing or no, is compelled to return. Being a conscientious fellow, he obeys the call and tries to find ways to save Margal Steep. But the mantees refuse to negotiate unless he can somehow persuade Girelf to accept her own responsibilities as heiress, and she will not. An attempt to destroy the dam fails miserably.

And when Barq seeks the Arbiter's consul half the world away, he is sent on a long space voyage only to learn that he must somehow infiltrate the wendish archives and purloin a mysterious data cube. It's not quite that simple, for Barq must run back and forth a few times before he gets that far, but that's the thrust of the matter, and it's no accident that his sexual history plays a vital role in his final success.

A word of warning for those who might object: This one's a bit raunchy. However, it's a very entertaining tale based on an interesting setup and blessed with a number of believable characters. The flaws are two: First, toward the end events accelerate so much the reader feels Douglas is surely skipping over whole chapters (per-

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haps he had to edit down a too-long manuscript). Second, the Arbiter seems a little too much in charge of serendipity; this might be acceptable if the Arbiter had to deal with only one or two worlds, but Douglas's very premise is that John Minder XXIII must oversee thousands of worlds; this strains credibility.

Still, I'm looking forward to the next entries in this series, for the first two of which ROC provides a glimpse in the form of brief excerpts.

You've all heard science fiction called "that Buck Rogers stuff." The epithet tracks back to a story by Philip Francis Nowlan, "Armageddon 2419 A.D.," published in 1928-29, turned into a comic strip conceived by John Flint Dille and written by Nowlan until his death in 1940, after which it was continued by others (including Fritz Leiber and Judith Merrill) until 1965. There was even a serial movie in 1939 and a "fixup" novel in 1962. The premise was that a World War I aviator, Anthony "Buck" Rogers, was shifted five centuries forward in time to discover America overrun by Mongol hordes. Despite huge differences in technology, Buck adapted and excelled, defeating the enemies of freedom wherever and whoever they might be. Imitators included the Flash Gordon comic strip, a host of B movies, and forests worth of pulp fiction. It was everywhere, it lasted forever, everybody knew about it, and it really is no wonder that it came to be the favored label for science fiction.

What did the label mean? Amazing futuristic whizmoes, certainly, but also glandular adventure, simplistic thinking, racism, jingoism. It said science fiction was stylistically primitive comic strip stuff, aimed at people who can't think without moving their lips. It completely ignored—or tarred with the same broad brush—the more thoughtful echelons of the field.

Want to know what I mean? Then pick up a copy of **Buck Rogers: A Life in the Future**, "as told by" Martin Caidin. It comes from a publisher known for its fondness for low-echelon "sci-fi," and it doesn't do a thing to elevate the standard. What it does do is suppose that Buck Rogers lived in the second half of the century, could fly anything with wings, including 747s, and crashed at an air show in 1996. A secret government program turned him into a trapped photon packet before he could finish dying, and in that form he lasted until revived and repaired in the 25th century.

That is, Caidin has made Buck Rogers a creature of our day and our technology. He thus becomes rather less quaint and more believable. So, for that matter, does the technology and culture of the future, for Caidin has a fair hand for technobabble extrapolation. But the story is still comic book stuff, still mindless, still stylistically primitive. It's still embarrassingly racist too, for though Caidin is careful to make the good guys a mixed bunch, the enemy is still the classic "Yellow Peril."

If that's all you want, go for it. But anything else reviewed this month is better value for your money. ■

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BRASS TACKS

Dear *Analog:*

I haven't written a letter to the editor in the forty some years I've been reading your magazine and its predecessors.

Harry Stine's guest editorial (June issue) probably annoyed me more than anything I have seen in all that time. The central theme is exactly right, but it's a bulls'-eye on the wrong target.

America was not built by politicians and bureaucrats, scientifically trained or otherwise. As long as the future of space depends on government money, space travel has no future.

I'll cheerfully admit that without government support Columbus would still be sitting at the dock. It might have taken a century to build a transcontinental railroad—but it would have been built.

When American industry finally gets weaned from tax-supported "innovation" we might see a little of the real thing. The real engineers are out there—what they need is someone with some guts to put them to work.

Our modern brand of "risk-takers" aren't going to take any risks—as long as they can get the government to do it for them. The goal should be to get the government out of the space business. If we do, and we don't have a manned space station in five years, we probably don't deserve to have one.

GERARD PIERCE

via the Internet

Dear Dr. Schmidt:

Before we can begin the climb out of our earthly cradle, relatively cheap, reasonably safe and reliable access to orbit is necessary. To make that a reality the money community must be persuaded that such access is realistically obtainable; the "giggle factor" must be eliminated. With all respect to authors Zubrin and Clapp, the introduction of the "Black Horse" APT aero-spaceplane does nothing to further that cause.

If either of Messrs. Zubrin or Clapp know an investor willing to put money into a theoretical transport system that requires a flying "main stage" (the tanker) to transfer 73 tons of propellant component at altitudes exceeding 40,000 feet and which, at the end of the day, puts only one-half ton into orbit, please let me know—I have a bridge for sale. I respectfully submit that advocacy of the APT concept is not the way for commercial space entrepreneurs to be taken seriously. Unless *Aurora* exists, the space-going

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airplane is an evolutionary dead-end.

There is only one example of a genuine SSTO that has actually flown, albeit in prototype form. That is the DC-X. To repeat: the Delta Clipper prototype, the DC-X, is *the* one and only prototype SSTO that actually, really exits in a touchable form which puts it years ahead of its competition.

Benefits arising from ballistic flight were dismissed too casually. Landing or launching, a Delta Clipper requires only a hardstand of a diameter large enough to attenuate the rocket wash. This is in contrast to the mile or so of paved runway required by any /HL concept. Vertical ascent and descent means minimum vulnerability to tropospheric disturbances (e.g., thunderstorms) as opposed to a space plane that must spend a considerable time in that layer, including the critical propellant transfer.

Self-ferrying is accomplished by short, ballistic hops; not fuel-efficient, but easily done. Delta Clipper is planned to have a powered, engine out abort capability; if all else fails, a parachute descent is the fail-safe reserve. No need to worry about plowing up a school or residential neighborhood with the Delta vehicle family. Granted, the /HL concept vehicle may have more cross-range capability; however, as a spaceplane it needs it.

As for payload integration, how can that be an issue? The vast majority of commercial payloads that will exist when a workable orbital access system becomes operational haven't been built yet. On that day, people will be making efforts to fit the cargo to the ship, not the other way around.

The NASP exists as an interesting engineering and research study which reminds us how very difficult hypersonic flight is. All SSTO concepts save one exist as slide shows, beautiful art work, tables, and graphs. It must be stated again and again and again until it's understood: there *is* an SSTO vehicle. It has flown as a proof of concept. It exists. It's real. Maybe it's not perfect, but *it's good enough.*

Unless we stop dithering around with this or that design rehash and focus on the one vehicle that exists in the here-and-now, tomorrow will always be tomorrow. The debate over VTO/VL, VTO/HL, or HTO/HL is over; VTO/VL has won. If any of the other concepts had overriding advantages, exemplar proof of concept vehicles would have been built by now. They weren't; DC-X was. DC-X worked. Case closed. Let's start figuring out what services LEO-Access Inc. will provide and what markets may need them. How much to charge per pound for 90 minute point-to-point transport anywhere on the globe? Whether to concentrate on a few large launch complexes or borrow from the early days of aviation and make every hamlet with a pasture and room for cryogenic tanks a potential rocket port? What help will be needed to wade through the inevitable morass of government regulations? If we are to have a future beyond Earth, tomorrow must be today. Let's get on with it.

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Dear Dr. Schmidt,

I have enjoyed *Analog* for many years, now, and commend you on an excellent job. Your stories and articles are really first-rate.

But I was surprised by Charles Sheffield's dark and dismal view of the future. I didn't think you allowed that. To bring a little hope for the future, allow me to suggest to *Analog* readers Eric Lerner's book, *The Big Bang Never Happened.* He believes that the "evidence" for the Big Bang can be more readily explained with a "steady-state" model, in which the Universe uses plasma physics to renew itself on a continuing basis.

Such a model makes beginnings and endings moot. While this may be disheartening to some, (how can one understand or quantify true Eternity?!) it also means that intelligent races can potentially live forever. Of course, this increases the urgency of the question "Where are They?" since with an infinite past, there should be an infinite number of races out there. But negative evidence is no evidence. We will have our answers only when we go out and get them. And the answer to that particular question may not even be *in* our Galaxy. We *really* need an exponential FTL drive!

LARRY HOOTEN
23410 Ellis Ave.
Perris, CA 92570

I don't know whether you were kidding about "I didn't think you allowed that," but I certainly don't insist that people slant the evidence or their interpretations to make everything look rosy! (And from a personal point of view, I certainly don't find myself depressed by Sheffield's model. I didn't expect to live anywhere near that long anyway!) I realize that a few, like Fred Hoyle and Eric Lerner, still prefer a steady state model. I'm perfectly willing to publish an article about their view, if one of them sends me a suitable one. Most scientists, though, currently consider the available evidence more likely to result from some variant of the Big Bang—as described by Sheffield.

Dear Dr. Schmidt,

I enjoyed your editorial in the July 1995 issue. I have always been more worried about the "Right Wing" destroying freedom than the "Left." The liberals just try to spend us into oblivion and most people can see where that will lead before it gets too far; the real problem is those who want to legislate what actions one can take.

In that connection, I would like to recommend a book to you. It is called *The Ominous Paralells, The End of Freedom in America* by Dr. Leonard Peikoff, Stein and Day, NY 1982, ISBN 0-8128-2850X. It is the most lucid explanation of this problem—and a solution, that I have ever seen. You will find it quite interesting.

I would also like to comment on "The Long-Term Future of the Universe" by Charles Sheffield. As a layman I cannot dispute much of the the article, nor do I wish to. But I do have a problem with the following sentence on page 76, second column: ". . . what was there before the Universe existed? This is a reasonable question, but not an easy one."

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I disagree that this is a reasonable question. In fact it is not a question at all, but a fallacy. Time is a relationship between things that exist, specifically the rates at which they change relative to one another. The Universe is a concept that refers to *All That Exists.* All means All, including Time itself; time is in the Universe, the Universe is *not* in Time.

The Universe, therefore, *cannot have an age!* I realize that most scientists think cosmos (i.e., space, energy fields, and so on) when they say Universe, but if you think about it, that is a mistake because it presupposes that time can have some meaning outside of the things it relates, and that is self-evidently false. Time presupposes objects that are related and objects are what make up the Universe. There is no alternative to this.

I would be interested to read your comments and those of Dr. Sheffield.

GREG CZORA

via the Internet

The author replies. . . .

The definition you choose to adopt for the Universe, namely, that it is a single four-dimensional object which includes time and everything else, is certainly a permissible one. It was used by Einstein himself, for example, when he said that he thought that the Universe is "complete," meaning that it is a single well-defined structure in four-space (this, as a by-product, rules out any possibility of free will).

However, I do not think that yours is a very productive definition, nor is it the one that most people use when they are discussing cosmology. For instance, with your definition you should not have been able to get past the title of my article.

"The Long-Term Future of the Universe" is a meaningless phrase if the Universe includes time, does not exist in time, and can therefore have neither past nor future.

When we talk about "the age of the Universe," there is an implicit understanding that what is being discussed is a three-dimensional space that evolves through time. In this case, it makes sense to ask what the "early" Universe was like, or what the "late" Universe will be like, because the very idea of an "early Universe" implies that time and the Universe can be discussed separately.

One can also, if one accepts the Big Bang theory, ask the question, "What came before the Big Bang?" And some will offer the answer, that the Universe undergoes an infinite cycle of expansions and contractions, which have been going on forever. At this point, however, the discussion is not physics but metaphysics.

CHARLES SHEFFIELD

Dear Stan:

I must admit that I don't always read your editorials, but only because your topic isn't always one that holds my interest. As a result I usually read about 75% of them. But I must say that your editorial in the July 1995 double issue happened to hit home on more than one count.

"Deathwatch for Freedom" is a subject that has long held my interest. Your eloquent summation "Your freedom to swing your arm ends where

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my nose begins" is exactly how I feel. If any of us is to have any freedom we cannot deny others their own freedom, as long as it does harm to no other person or group of people. By harm I mean vicious, cruel, and often thoughtless injury. I sometimes think that I am old-fashioned but I live by the Golden Rule. It works for me and has stood me in good stead for over 40 years.

After I-don't-recall-how-many years of affirmative action and the odious specter of political correctness, one cannot speak one's mind for fear of being visited by a squad of lawyers intent on making a large killing out of a poor choice of words.

The second point of interest of your article stems from a recent workshop I was required to attend at my workplace (a very large company in the Midwest) entitled "Discover Diversity." I normally love attending workshops because they afford me the opportunity to learn something, but this one held no such promise for me. The company's aim was to show their employees that they should treat all people with respect and dignity. Pardon me, but if you haven't learned this lesson by the time you are in your early twenties or older you are not likely to learn it at all.

It was a day-long workshop and I listened to what they had to say, offering comment when it was solicited. After about three hours, however, I could not restrain myself any longer. I finally spoke my mind saying that I was fed up with trying to be "politically correct," and living in fear of a lawsuit. My complaint about another person does not stem from their race, color, sexual preference, or anything along these lines. When I have a beef about someone it is because the person keeps trying to demonstrate how big a fool they are. It has always been my belief that I should treat those around me in the manner which they demonstrate they wish to be treated. I have dealt with prostitutes as ladies and people whom others would take as scum as respectable persons, until they show they want to be treated otherwise. There is no cost involved and quite often I have found that these people have been worthy of this treatment.

I learned at an early age that all people, regardless of any circumstances, should be treated with respect and dignity. To do less invites similar treatment and I will never again tolerate such handling. To take away an individual's respect and dignity is to make a truly dangerous enemy. I have always believed that the only reason to do the right thing is because it is the right thing to do, not for political correctness or presumed gain.

Too many times in recent years I have seen people demand protection from insult or perceived injury while denying others similar freedom. Your example of the professor is a sorry commentary on life in our present society. Because of the bitter accusations of a very few and against overwhelming support to the contrary a good man was destroyed. No one put a gun to the heads of the complaining students and forced them to stay in that class. They could have transfered to another class or withdrawn at any

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time. I have been in a similar situation myself and when I found myself vehemently disagreeing with the professor, I voiced my comment and politely left the class to those who preferred to stay.

It seems to me that there are an overwhelming number of people today who are of the opinion that theirs is the only just cause and that all dissent should not be tolerated. Perhaps I am mistaken but I seem to remember something about this being the land of the free and the home of the brave. Did I miss something here?

At any rate, Stan, I just wanted to pass along my comments on a topic that holds great meaning for me. Keep up the good work. Yours is a publication which I have enjoyed for many years. It is a pleasure to find *Analog* in my mailbox every month.

BOB CRAYCROFT

via the Internet

Dear Stan,

I thought your editorial in the July 1995 issue was right on target, and, in light of the events occurring since you wrote it, almost prescient.

The quotation you used in the concluding paragraph, "Eternal vigilance is the price of liberty" has long been one that I have used myself, and I too have always attributed it to Thomas Jefferson. However, something prompted me to drag out my *Bartlett's* and lo and behold (see enclosed copy), it is attributed to John Philpot Curran! I then got out my Jefferson sources, and could find no record of him using this expression. I just thought you would like to know.

JACK E. GARRETT

Jamesburg, NJ

Curran may well have the prior claim on this one. References don't always agree on the sources of these odd quotes—which may mean nobody really knows! ■

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UPCOMING EVENTS Anthony Lewis

1–3 March

ASTRONOMICON 5 (Rochester area SF Conference) at Radisson Inn, Rochester, NY. Guest of Honor—Robert J. Sawyer; Fan Guest of Honor—Bjo Trimble. Registration: $30. Info: The Rochester Fantasy Fans, PO Box 1701, Rochester, NY 14603-1701. (716) 342-4697; ralston@aol.com or rff@aol.com

15–17 March

LUNACON '96 (New York City area SF conference) at Rye Town Hilton, Rye Brook, NY. Guests of Honor—Terry Prachett, Esther Friesner; Visual Humor Guest of Honor—Phil Foglio; Fan Guest of Honor—Bruce Pelz; Origami Guest of Honor—Mark Kennedy. Registration: $33 until 15 February, higher at the door. Info: Lunacon '96, Box 3566, New York, NY 10008. lunacon@lunacon.org

20–24 March

INTERNATIONAL CONFERENCE ON THE FANTASTIC IN ARTS (academically oriented SF conference) at Florida Atlantic University, Boca Raton, FL. Guest of Honor—Greg Bear; Special Guest—Brian W. Aldiss; Scholar Guest—Tom Shippey. Info: IAFA, College of Humanities, 500 NW 20th, HU-50, B-9, FAU, Boca Raton, FL 33431. (717) 532-1495.

22–24 March

MIDSOUTHCON 15 (Midsouth SF conference) at Brownstone Hotel, Memphis, TN. Guest of Honor—Barry B. Longyear; Artist Guests of Honor—Frank Kelly Freas & Laura Brodian Freas; Fan Guest of Honor—Cullen Johnson; Special Guest—Paul Darrow. Registration: $25 until 1 March, $30 thereafter. Info: MidSouthCon, Box 22749, Memphis, TN 38122. (901) 274-7355.

29 August–2 September

L.A.CON III (54th World Science Fiction Convention) at Convention Center, Hilton, and Marriott Hotels, Anaheim, CA. Guest of Honor—James White; Media Guest of Honor—Roger Corman; Fan Guests of Honor—Takumi and Sachiko Shibano; Special Guest—Elsie Wollheim; TM—Connie Willis. Registration: $90 until 30 June, $110 until 31 December, then higher. Child-in-tow (3-12): $35, infants: free. Supporting: $30. This is the SF universe's annual get-together. Professionals and readers from all over the world will be in attendance. Talks, panels, films, fancy dress competition—the works. Join now and get to nominate and vote for the Hugo Awards and the John W. Campbell Award for Best New Writer. Info: L.A.Con III, c/o/ SCIFI, Box 8442, Van Nuys, CA 91409. lacon3-info@netcom.com

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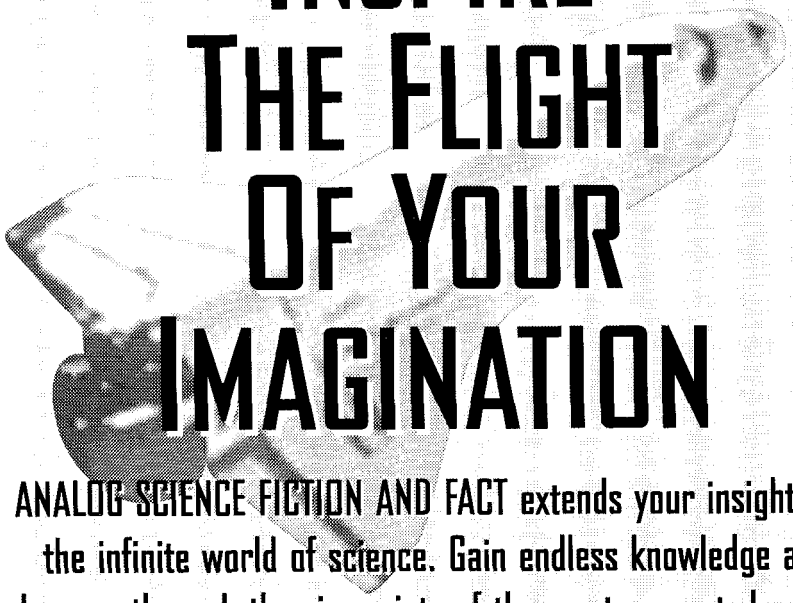

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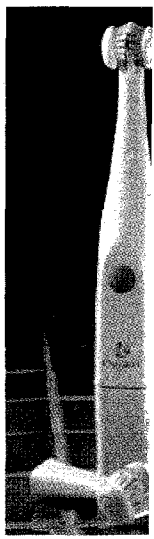

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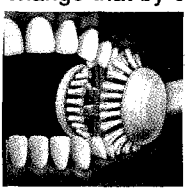

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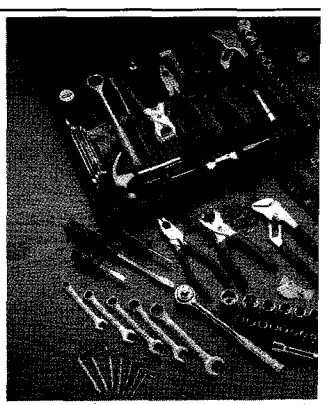

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